STATE OF INDIANA

GEORGE N. CRAIG, GOVERNOR

REPORT OF INVESTIGATION

MONROE RESERVOIR
SALT CREEK NEAR HARRODSBURG, INDIANA

FOR

FLOOD CONTROL, INCREASING LOW FLOW
AND ALLIED PURPOSES

REPORT NO. 9

FLOOD CONTROL AND WATER RESOURCES COMMISSION

1330 WEST MICHIGAN STREET INDIANAPOLIS 7, INDIANA

DECEMBER 1956

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SYLLABUS

This report was directed by the 1955 Indiana General Assembly (Acts 1955, Chapt. 74, p. 143) for the purpose of determining the scope of storage, relationship of water resources uses and all available benefits relating to a proposed reservoir in the Salt Creek valley of southeastern Monroe and parts of Jackson and Brown Counties.

It has been determined that it is feasible and would be beneficial to the State to construct a dam at Mile 25.65 on Salt Creek, about two miles east of Harrodsburg, Indiana, for the dual purpose of flood control and increasing low flow downstream from the dam. The proposed reservoir would have a gross storage capacity of 446,000 acre-feet which amounts to 19.0 inches of runoff from the drainage area of 441 square miles. Of the gross storage, 260,000 acre-feet would be available for flood control, 159,000 acre-feet for increasing low flow and 27,000 acre-feet for future siltation. These volumes are equivalent to 11.1, 6.8 and 1.1 inches of run-off respectively.

The maximum flood control pool would be at elevation 556 and would create a lake of 18,500 acres. The normal pool level, below which water would be stored for increasing the low flow downstream, has been set at elevation 538 and would create a normal lake surface of 10,700 acres. Sedimentation storage would be below elevation 515 at which the lake area would be 3,300 acres.

The average annual benefits that would be derived from the project have been estimated at $901,000, of which $398,000 is credited to flood control and $503,000 to increasing low flow downstream from the dam. Considerable protection against floods would extend downstream to rural and urban areas along the East Fork of White River, White River and Wabash River. Benefits would also extend to the Ohio and Mississippi Rivers. Benefits from regulated release of stored water to increase low flow would extend downstream to these rivers. The greater protection from floods and the enlarged supply of water for industry will be of tremendous value to the entire economy of southern Indiana.

The total cost of the project is estimated at $9,500,000 and the average annual charges are estimated to be $376,000, including $35,000 for annual operation and maintenance.

The reservoir is economically justified on the basis of the ratio of average annual benefits to annual costs of 2.40 to 1.

Monroe Reservoir has been planned for joint financing by the State and Federal governments, in accordance with existing Federal policy relating to multiple-purpose projects. Under present Federal policy the State would participate in the cost of flood protection in relation to land enhancement benefits, the cost of providing storage for increasing low flows downstream, and a proportionate share of the operation and maintenance costs. The share of the cost to be borne by the State is estimated to be 54.1 percent of the first cost of the project which, based on present conditions and prices, would amount to $5,141,000. Enactment of a new Federal policy could change this cost allocation between Federal and non-Federal interests.

The report recommends that Monroe Reservoir be authorized for construction by the State and Federal governments at a total estimated cost of $9,500,000 and $35,000 annually for maintenance and operation.

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INTRODUCTION

General. - The need for the development of water resources projects to improve the availability of water from surface sources in Southern Indiana has long been recognized. The rocks underlying the region are highly impermeable and ground water from shallow wells is very difficult to obtain or is non-existent. Deep ground waters are generally highly mineralized and not suited to municipal or industrial use without treatment. The streams are erratic in their flow, varying from occasional severe flooding to long periods of very low flow.

The East Fork of White River and its tributaries are subject to destructive floods and serious overflows occur at frequent intervals. Low flows during drought periods, particularly on the tributaries, are inadequate for municipal or industrial supply or the transport of waterborne wastes. Consequently, a number of towns in the region recently have turned to the construction of reservoirs to store water during periods of excess runoff for use during later periods of deficient flow.

The destructiveness of flood flows and the inadequacy of many water supplies have been recognized locally for years and have prompted a public demand that corrective measures be taken. This demand led to authorization of a special study of the feasibility of constructing a water-storage and flood-control reservoir on Salt Creek in Monroe County, Indiana.

Authority. - This report was directed by an Act of the Indiana General Assembly, passed at the Eighty-ninth Regular Session and approved March 8, 1955 (Acts 1955, Chapt. 74, p. 143), which reads as follows:

> "SEC. 1. The Indiana General Assembly recognizes that continued flood dangers in several areas of the State and severe shortages of water in other areas alike create handicaps to the proper development of a sound economy that will be of greatest benefit to the citizens of the State. The Indiana General Assembly recognizes that undue delay in acting to correct such flood dangers and such water shortages would be injurious to the welfare of the State.

The Indiana General Assembly hereby authorizes the Indiana Flood Control and Water Resources Commission to expand its activities in the development of retention reservoirs for both flood control and water supply storage purposes due to the fact that this type of surface water control has proven successful for such purposes over the last twenty years throughout the United States.

SEC. 2. * * * * * * * * * * * * * * *

SEC. 3. The Indiana General Assembly recognizes that the State of Indiana has responsibilities to its citizens for the creation of storage reservoirs, where needed, to enhance future sources of water supply for farm and city or town residents, and there is hereby appropriated the sum of thirty thousand dollars to the Indiana Flood Control and Water Resources Commission to obtain an engineering, economic and geologic planning survey, either by its own engineering staff or by a civil engineering firm which the said commission may employ, to determine costs, scope of storage, relationship of water resources uses, and all available benefits, and similar information relating to a proposed water supply reservoir in the Salt Creek valley of southeastern Monroe County, parts of Jackson County, and parts of Brown County. A report with recommendations shall be submitted to the 1957 Indiana General Assembly for its determination as to appropriation of funds for the start of construction of said Salt Creek Reservoir."

History. - In 1946 Professor I. Owen Foster, School of Education, Indiana University, being concerned with the likelihood of a shortage of water for the City of Bloomington, suggested to the Indiana Flood Control and Water Resources Commission the possibility of a reservoir on Salt Creek. His proposed site, about 2 miles downstream from State Highway 46, was examined by the Commission, but no detailed surveys were made.

In the summer of 1947, Commission staff members and an engineer from the Corps of Engineers, U. S. Army, at the suggestion of Governor Ralph F. Gates, examined the basin and recommended that the dam, if constructed, be placed near the lower end of the stream, in order to take fullest advantage of flood-control possibilities.

On June 15, 1949, a citizens' committee from Bloomington placed on record with the Commission a petition signed by over 800 persons asking that a dam be built on Salt Creek, to give Bloomington a source of additional water. The city did not wait for construction of Salt Creek Reservoir for this purpose, but turned to Bean Blossom Creek, on which a storage reservoir was completed in 1953.

On August 10, 1954, the Chief of Engineers authorized the Louisville District of the Corps of Engineers to prepare a review report pursuant to a resolution adopted July 30, 1954, by the Committee on Public Works, United States Senate, which reads as follows:

> "RESOLVED BY THE COMMITTEE ON PUBLIC WORKS OF THE UNITED STATES SENATE, That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby, requested to review the report printed in House Document Numbered 100, Seventy-third Congress, First Session, and subsequent reports on the Wabash River and tributaries, Ohio, Indiana, and Illinois, with a view to determining whether any modifications of the recommendations therein should be made with respect to the proposed Monroe Reservoir site and other flood control measures on Salt Creek and tributaries, Indiana."

On March 8, 1955, the Indiana General Assembly appropriated funds for a reservoir survey in Salt Creek Valley, giving the investigation impetus.

Consultation with interested parties. - Several consultations have been held with interested parties. On March 25, 1954, the plan under study was advocated and explained by Indiana Flood Control and Water Resources Commission staff members at a public water resources meeting sponsored by Southern Indiana, Incorporated, in French Lick-Sheraton Hotel. Southern Indiana, Incorporated, an organization representing business interests, service clubs, and chambers of commerce throughout Southern Indiana, is dedicated to improving the economic status of the region. Additional meetings have since been held with this group, service clubs, and others.

Engineers of the Commission have discussed with county and other officials the impact of the reservoir on local economies. These included county commissioners, highway and school superintendents, and a representative of the U. S. Post Office. Because of Federal Aid roads in the reservoir area, the Bureau of Public Roads has been advised and its engineers consulted on these matters.

Prior reports. - A report that was perhaps the first comprehensive study of the Wabash River basin was prepared by the Corps of Engineers pursuant to the authority provided in House Document No. 308, 69th Congress, 1st Session, and the Flood Control Act of May 15, 1928. This document was published as House Document No. 100, 73rd Congress, 1st Session ("308 Report on the Wabash River basin) and covered navigation, flood control, power, irrigation, and other related subjects. No reference was made to Salt Creek, but the recommendation of the Chief of Engineers on the basin as a whole was as follows:

> "* * * * * * I, therefore, report that improvement by the Federal Government of Wabash River, Ohio, Indiana, and Illinois, for navigation either alone or in connection with power development, flood control, or irrigation or any combination thereof, is not deemed advisable at the present time."

A report by the Chief of Engineers, U. S. Army, entitled "Comprehensive Flood-Control Plan for Ohio and Lower Mississippi Rivers", dated April 6, 1937, was published by the Committee on Flood Control, House of Representatives, as Committee Document No. 1, 75th Congress, 1st Session. This report reviewed prior reports which presented plans for the control of floods in the Ohio and Mississippi River basins and was directed to the further control measures which became advisable as a result of the great flood of 1937 on the Ohio River. The report recommended construction in the Ohio River basin of additional flood-control reservoirs and levees and floodwalls at cities and towns. Eight of the recommended reservoirs were located in the Wabash River basin, one of which was to be constructed at Shoals on the East Fork of White River by the Corps of Engineers when funds for that purpose were appropriated by Congress.

The possibility of obtaining flood storage on Salt Creek was first mentioned in a survey report prepared by the Louisville District, U. S. Corps of Engineers, in compliance with Section 6 of the Flood Control Act approved August 11, 1939, (Public Law No. 397, 76th Congress, 1st Session. The report was entitled "Survey Report on Flood Control, Wabash River and Tributaries, Indiana and Illinois", dated July 1, 1944, and published as House Document No. 197, 80th Congress, 1st Session. The report, in discussing the possibility of substituting a number of reservoirs in the headwaters of the East Fork White River watershed for a single reservoir on the main river above Shoals, stated: "Another tributary with considerable drainage area is Salt Creek and in this instance conditions are somewhat more favorable (than on other tributaries). The Chief of Engineers, in his letter of transmittal of that report to Congress, recommended that the Shoals Reservoir be deleted from the comprehensive plan for flood control and other purposes in the Ohio River basin because of strong local opposition. The adoption of that recommendation by Congress in the Flood Control Act of 1946 then made the tributary reservoirs of far greater importance.

In January 1949 the Chief Engineer of the Flood Control and Water Resources Commission prepared a report on "White River Basin Needs" for the Commission, in which he stated "The Salt Creek survey can be highly recommended for further study because there is a tremendous opportunity for storage in this basin and a very considerable watershed to be controlled." That report was submitted also to the Corps of Engineers at a public hearing held on January 28, 1949, in Seymour, Indiana.

None of these reports went further than to recommend that more thorough investigations be made to fully determine the merits of the Salt Creek reservoir site.

The Soil Conservation Service, U. S. Department of Agriculture, in October 1949, prepared a report entitled "Survey of Floodwater and Sediment Damage by Storm of October 31, 1949", in which appraisals were made of damages to crops, improvements, highways, and lands in the Salt Creek valley from its source on the North Fork just south of Peoga, Brown County, to its mouth in Lawrence County.

In 1950 the Soil Conservation Service also prepared an interim survey report entitled "East Fork of White and Patoka River Watersheds, Indiana", in which a program of runoff and water-flow retardation and soil erosion prevention was recommended. The plan did not include reservoirs in the Salt Creek watershed.

Cooperation. - The investigations for this report have been carried on in cooperation with the Louisville District, U. S. Corps of Engineers, which has been authorized to make a concurrent study. The program of investigation has been closely coordinated with the Louisville District to provide for a division of work between the Federal Government and the State and to avoid unnecessary duplication.

Acknowledgment is made to the staff of the Indiana State Geologist for preparing a report on the geology of the region providing subsurface data for the dam and spillway sites obtained from borings, soil samplings and geologic and seismic studies.

An economic survey of the Salt Creek valley was undertaken by the Indiana University School of Business at the request of the Commission and a report prepared. That work furnished the basis for the economic appraisal contained in this report.

The assistance of the U. S. Geological Survey in obtaining special stream flow information relative to the investigation is acknowledged.

The Indiana Economic Council furnished data on present and future industrial developments in the region and arranged interviews with interested parties.

The United States Forest Service provided detailed information relative to the timber resources of the area.

SCOPE OF REPORT

General. - This report is concerned principally with determining the merits of a proposed reservoir on Salt Creek with respect to its economic justification, based on benefits accruing from its use for flood and low-water control, to determine a project best suited to the requirements of local interests and which would not adversely affect the comprehensive plan for the White River basin.

In the course of the investigation, attention was paid to the need for supplementing low flows of the East Fork of White River and White River, for alleviating stream pollution, improving the quantity and quality of industrial water supplies, and in general to providing beneficial distribution of stream flow for the region. Studies were also made of benefits to be obtained from the reduction of flood stages along the East Fork of White, White, and Wabash Rivers through the temporary storage of flood waters originating in the Salt Creek watershed.

Surveys and other investigations. - The research for this study consisted of an examination of the valleys of lower Salt Creek, East Fork of White River downstream from Salt Creek, and White River below the confluence of East and West Forks, to obtain all pertinent information relative to dam sites, agricultural and urban flooding, and the need for augmenting low flow downstream.

The Indiana Flood Control and Water Resources Commission staff prepared general location maps and capacity and area curves from the topographic maps that cover the reservoir area.

The Commission surveyed the stream valley from the dam site to the mouth, obtaining low and high-water profiles and flood-plain cross sections for use in determining location and extent of agricultural land flooding.

The Indiana Geological Survey, at the request of the Commission, prepared a report on the geology, mineralogy, and geophysics of the area. This included a geologic evaluation of the dam and spillway sites by surface examinations and a study of borings along their axes.

Additional field surveys were made and maps prepared by the Louisville District, U. S. Corps of Engineers, to determine the availability of fill materials for the dam. The Corps also made field examinations of damages caused by floods which, when combined with studies of flood frequencies, formed the basis for determination of average annual flood damages downstream from the proposed Monroe dam site.

REGIONAL GEOGRAPHY

General. - Salt Creek is a tributary to East Fork of White River at Mile 143, a short distance downstream from Bedford, Indiana. The location within the White River basin of the creek and the project under study are shown on the General Map, Plate I.

The drainage area of Salt Creek above its confluence with East Fork of White River is 647 square miles. It drains approximately two-thirds of Brown County, the lower half of Monroe County, and parts of Lawrence and Jackson Counties.

The watershed approximates a fan in shape, with two large forks of about equal size joining just west of the Monroe-Brown County line to form the main stream. It lies within a region of rugged topography with total relief varying from 195 feet at the dam site near the south line of Monroe County, to 365 feet in a district east of the North Fork, where the upland reaches an altitude of 860 feet.

Salt Creek is the master stream of the region. Its size, as compared with the valley which it occupies, indicates that in relatively recent geologic times it has carried a much larger volume of water than it does today. That water was ice melt from the Illinoian and Wisconsin glaciation, which advanced to, but did not overrun the Salt Creek valley.

Salt Creek is also an aggrading stream, which is continuing to fill its valley with deposits of fine silt and clay eroded and transported from upstream areas and adjacent highlands. In places the stream course is bordered by small natural levees and areas of backswamp which lie between the stream and the valley walls. Because of this aggradation, the stream banks are low and the adjacent lands subject to overflow by relatively minor floods.

The main stream, with a gradient of about 2 feet per mile, is much flatter than its tributaries, which have gradients of up to 30 feet per mile. These steep side streams produce more erosion and faster runoff than would be the case if they were more nearly the same grade as the main stream.

The chief topographic feature of the watershed is the deeply cut, flat-bottomed nature of the valleys of the North and Middle Forks, which range in width from one quarter to one mile. In a few places the valleys are flanked by narrow terraces which rise 10 to 20 feet above the flood plain, but these terraces are not continuous over any great distance. Steep slopes rise abruptly from the valley floor to the relatively flat-topped uplands. These uplands are sharply cut by many small streams, which are deeply incised where they flow over the softer rocks of the region.

Geology. - The proposed dam site and reservoir lie within and near the western border of the physiographic province which has been designated the Norman Upland. Its boundary is marked by a line along which the topographic features change from deeply dissected clastic rocks to those of a rolling limestone plain which includes sinkholes as a distinctive feature.

All bedrock in the region was originally deposited as marine or deltaic sediments, early Mississipian in age. Siltstones, sandstones, shales, and limestones of the Borden Group of formations are overlain successively by Harrodsburg and Salem limestones. Bedrock is everywhere present in the valley at relatively shallow depth. The valley floor has been cut to a depth of about 65 feet below its present elevation and filled back by Pleistocene and Recent alluvium.

The minimum altitude of the Harrodsburg-Borden contact adjacent to the proposed reservoir is approximately 590 feet. These rocks are siltstones and sandstones, fine-grained, cemented with clay, relatively free of joints and bedding planes, and highly impermeable.

The principal structural feature of the region is the Mt. Carmel fault block. It crosses in a north-south direction just below the confluence of the North and South Forks, following generally along the line of Saddle Creek and the North Fork, leaving the valley via Brummett and Stevens Creeks.

Geologic considerations indicate that the Salt Creek valley is well adapted to usage as a reservoir. Rock lithology, permeability conditions, and geologic structure insure a minimum of water loss by leakage. The dam site is favorable.

Land use. - The soils of the Salt Creek watershed and, in fact, of much of the region, are of the upland type, too poor to produce crops sufficient to provide those who farm them with a good living. The scars of gulley erosion are a common feature of the uplands and the run-down appearance of farmhouses and buildings testifies to the futility of cultivating these poor soils. On the other hand, the bottomland soils of the valleys, while not extensive, are much richer than those of the uplands and the farmers who own valley farms are relatively prosperous. They do not have a serious erosion problem. Rather, they are faced with the necessity for providing drainage, and because the streams are aggrading, the bottomlands are subject to frequent overflows and crops are often lost through flooding.

The lands of the region have a particular value, in that they are growing large quantities of timber, from which may be harvested lumber, veneers, pulp, charcoal, and many other forest products. The U. S. Forest Service, in its pamphlet, "Indiana's Forest Resources and Industries, 1956", states that 72 percent of Brown County, lying athwart the upper reaches of the Salt Creek watershed, is covered with forests. This is in contrast with Benton County, in the prairie area of northern Indiana, which is only 1 percent covered. Practically all of southern Indiana, with the exception of the valley of the Wabash, has over

20 percent forest cover with many counties having more than 60 percent. Most of this land is privately owned. There are several Federal and State holdings in tracts sufficiently large to furnish commercially important amounts of wood in individual sales. Much of the timber in the region is ready for harvest.

Maps. - The reservoir site is covered by quadrangle topographic maps of the U. S. Geological Survey issued in 1947, 1950, and 1956. These maps are prepared to a scale of 1:24,000 and contour interval of 10 feet. The Indiana Flood Control and Water Resources Commission had maps of the dam site prepared under contract by photogrammetric methods and has itself prepared a general map of the reservoir and surrounding area and of the White River basin.

Economic development. - The Salt Creek valley was settled rather early in the history of Indiana, by people migrating along the Ohio and Wabash Rivers and their tributaries, in search of new lands. To these pioneers timber indicated good soil, and they settled in the hill country first. Soon after the forest cover was removed, erosion set in on the soil and its fertility was rapidly reduced. As a result, the farms lost their productivity and the farm income declined.

For several years the limestone industries at Bedford and Oolitic have provided employment for a considerable part of the working population in the region and more recently industries have settled in Bloomington, opening up a number of job opportunities there.

The four counties surrounding the reservoir area, Monroe, Lawrence, Jackson, and Brown, have shown little or no growth in population between the 1940 and 1950 census counts, except in the city of Bloomington. That city grew as the result of industrial expansion, but the rate of growth is obscured because the 1940 census did not include the student population of Indiana University, while the 1950 census did. Prospects for future growth are best in Bloomington, where new industries are attracting workers to the area and where Indiana University is growing at a phenomenal rate.

TABLE I

POPULATION TRENDS IN REGION OF SALT CREEK

County	Population					
	1950	1955	1960	1965	1970	1975
Monroe	50,080	54,362	64,548	76,622	90,835	106,685
Lawrence	34,346	34,003	33,663	33,326	33,993	33,653
Jackson	28,237	29,225	30,217	31,274	31,769	33,501
Brown	6,209	6,215	6,311	6,406	6,502	6,598

The population trends in the four counties were studied in 1955 by the School of Business, Indiana University, and a forecast, based on statistics of the U. S.

Bureau of the Census, prepared especially for this report. The forecast for the four-county area, with projections by 5-year increments from 1950 to 1975, is shown in Table I.

The economic development of the four-county area is largely reflected in the gross incomes of the counties and the major sources of income. The latest available data on gross income in Indiana provide figures on the incomes from agriculture, maunfacturing, and wholesaling in the calendar year 1953. The figures for the four-county area are listed in Table II.

TABLE II

1953 GROSS INCOME IN REGION OF SALT CREEK

County	Source of Income		
	Agriculture	Manufacturing	Wholesaling
Monroe	$3,178,157	$31,667,287	$20,931,498
Lawrence	4,173,086	3,954,970	11,893,375
Jackson	8,763,255	10,103,911	7,295,896
Brown	468,780	8,291	232,317

A variety of items is manufactured or processed in the region, including lumber and other forest products, building stone, cement, gypsum, foods, electronic devices, chemicals, and metal and clay products.

The lands in the vicinity of the reservoir site are for the most part submarginal. They are not capable of producing crops of enough value to permit the collection of sufficient taxes to meet the needs of the townships, counties, and State. Financial aids in the form of agricultural benefits and subsidies and State grants for education, road maintenance, and public health are necessary and help to maintain an unbalanced economic system.

Maladjustment of land use is indicated in many ways. Abandoned farms and dwellings, low farm incomes, part-time farming, soil erosion, low property assessments, and meagre personal assets are common. All of these factors reflect the general poverty of the area.

The need for State support for education is an outstanding example of the financial problems of the area. Salt Creek Township, in Monroe County, toward the upper end of the reservoir, spent $40,242 for grade-school education in 1953. Only 30 percent of this came out of the township funds, the remaining 70 percent was furnished by the State. Any development in this region that will bring in additional taxes to the counties and their civil subdivisions will reduce the State's share of the burden for such purposes.

CLIMATOLOGY

Precipitation. - The normal annual precipitation for the Salt Creek watershed, as determined from records of the U. S. Weather Bureau stations at Bloomington, Indianapolis, Oolitic and Terre Haute, in or near the watershed, is 41.6 inches. The maximum annual precipitation recorded at the Bloomington gage was 60.72 inches in 1945 and the minimum 28.44 inches in 1940. The maximum monthly precipitation was 14.83 inches in January 1937, while a minimum precipitation of less than 0.1 inch has been recorded for various months.

Snowfall. - The average annual snowfall for the watershed is about 20 inches, with about 75 percent of the total occurring in the period of December through February. The snow rarely remains on the ground for more than a few days and, in general, is a small contributing factor to floods.

Temperature. - The normal mean annual temperature for Salt Creek watershed, based on the Bloomington record, is 54.0 degrees Fahrenheit. January is the coldest month with a normal temperature of 30.6 degrees, and July the warmest, averaging 76.7 degrees. Temperatures as high as 110 degrees above and as low as 20 degrees below zero have been recorded.

Based on 46 years of record at the Bloomington station, the earliest date of frost occurrence is September 14 and the latest May 26. The length of the growing season averages 183 days, extending from April 20 to October 20.

Storms. - Most of the storms that produce severe floods in the Salt Creek watershed are of cyclonic nature and travel from southwest to northeast. These storms are most prevalent during the winter but may occur even in late spring. Convective-type storms usually occur during the summer months and have produced some very high rainfall intensities. However, storms of this nature seldom produce serious floods because they are of small areal extent and are mitigated by the high infiltration and evaporation losses characteristic of the summer season.

Although no rain gages have been operated continuously over a long period in the Salt Creek watershed, the precipitation over the area in the past may be inferred from the record obtained at Bloomington by the U. S. Weather Bureau. Some of the larger floods have been caused by the short intense type of storm, such as those of January 4-5, 1949, and May 23-25, 1952, when the rainfall did not exceed 4 inches but was concentrated mostly within a 24-hour period. Some of the other large floods were caused by a prolonged series of storms, as in January 1937 and January 1950, in which accumulations of runoff from lesser amounts of rainfall built up the flood situation over a period of one to several weeks. In the prolonged series, the total amount of rainfall required to produce flooding conditions was two to three times that required in the short intense storms. The major storms observed at Bloomington have been tabulated in Table III.

TABLE III

RAINFALL DEPTH OF MAJOR STORMS
AT BLOOMINGTON, INDIANA

Year	Storm Period	Rainfall (Inches)	Year	Storm Period	Rainfall (Inches)
1875	Jul. 25 - Aug. 3	9.67	1950	Aug. 29 - Sep. 3	4.63
1910	Oct. 3 - 6	8.80		Nov. 8 - 9	2.79
1913	Mar. 23 - 27	9.20		Nov. 19 - 20	2.38
1916	Jan. 27 - 31	5.59	1951	June 25 - 29	2.97
1922	Mar. 26 - Apr. 1	5.57		Nov. 10 - 15	2.70
1927	May 18 - 19	2.58		Dec. 3 - 8	4.80
	May 23 - 25	1.44	1952	May 23 - 25	3.62
	May 27 - 31	1.38		June 21 -22	3.41
1930	Jan. 7 - 10	4.42		Aug. 14 - 16	2.05
	Jan. 12 - 14	2.82	1953	May 12 - 18	3.37
1933	Mar. 13 - 21	4.14		July 5 - 6	2.52
	May 8 - 16	3.32	1954	Aug. 1 - 4	2.32
1937	Jan. 5 - 25[a]	14.29		Oct. 11 - 16	2.98
	Jan. 20 - 25	5.71		Dec. 28 - 30	2.42
1938	Mar. 28 - 31	2.18	1955	Jan. 1 - 5	3.05
1939	Mar. 11 - 13	4.06		Apr. 11 - 14	2.62
1943	May 7 - 12	3.23		June 7 - 15	2.94
	May 14 - 21	2.84		July 15 - 17	2.26
1949	Jan. 4 - 5	3.80		Sep. 22 - 24	3.95
1950	Jan. 1 - 16	10.74		Nov. 14 - 16	2.66
	Feb. 12 - 15	3.12	1956	May 26 - 31	4.39
	Mar. 27 - 28	2.22		June 19 - 23	2.80

a. Principal storm during period Jan. 5 - 25, 1937.

Evaporation. - Evaporation for Monroe Reservoir has been estimated on the basis of data collected at Class A evaporation stations of the U. S. Weather Bureau at Evansville since May 1946 and at Indianapolis since April 1938. Records generally have been kept from April through October at both stations although some November records have been collected.

The evaporation rates at Evansville are the highest in the State, averaging about 10.5 inches more at that station than at Indianapolis during the seven-month observation season April to October. The monthly averages for the two stations (from data in U. S. Geological Survey Water-Supply Paper 1363, Hydrology of Indiana Lakes) together with estimated values for the Salt Creek area are given in Table IV.

TABLE IV

AVERAGE MONTHLY EVAPORATION
(Class A Evaporation Pan)

Place	Apr.	May	June	July	Aug.	Sept.	Oct.
Evansville	4.82	6.24	8.00	7.99	7.01	5.73	4.05
Salt Creek	4.21*	5.48*	6.71*	7.14*	6.27*	4.87*	3.24*
Indianapolis	3.74	4.90	5.72	6.48	5.70	4.21	2.62

*Estimated.

The evaporation figures for the Salt Creek area have been estimated to be somewhat nearer the values at Indianapolis than at Evansville because of the greater proximity of Indianapolis. The pan evaporation for the period December to March probably averages about 8.9 inches at Evansville, 7.7 inches at Salt Creek and 6.8 inches at Indianapolis.

The evaporation rates from pans are somewhat different from lake-surface rates because the water temperatures in the pans follow air temperatures more closely. The annual evaporation from a lake surface averages about 69 percent of the pan evaporation and may be approximated by months by applying to the pan evaporation figures the coefficients given in Table V.

TABLE V

COEFFICIENTS FOR CONVERTING
PAN EVAPORATION TO LAKE EVAPORATION

Month	Coefficient	Month	Coefficient	Month	Coefficient
Jan.	0.79	May	0.48	Sept.	0.86
Feb.	0.45	June	0.57	Oct.	0.95
Mar.	0.33	July	0.67	Nov.	1.03
Apr.	0.38	Aug.	0.77	Dec.	1.01

Water losses due to evaporation will be most noticeable during the summer months and will cause declining lake levels in drier years when the evaporation exceeds the inflow into the lake.

POTAMOLOGY

Stream-flow characteristics. - The topography, geology and soil characteristics of the Salt Creek watershed are such that a relatively high percentage of the precipitation from storms appears as surface runoff. Also, because nearly all the major storms over this watershed occur during the winter and early spring interception and transpiration by vegetation has little mitigating effect on flood runoff. For these reasons, this stream is an important contributor to flooding in the White River basin. By the same token, little water remains in storage in stream channels or in the ground following a storm and the stream has a small residual flow, reaching zero at times during the drier seasons.

The channel slope of the main stream increases from about 1 foot per mile along its lower reaches, below the dam site, to 9 feet per mile toward its upper end. The slopes of the tributary streams are materially steeper, some having a fall as great as 30 feet per mile. This gradient is in marked contrast with the East Fork of White River below the mouth of Salt Creek, which averages approximately 0.6 foot per mile.

Sedimentation. - The steepness of the upper Salt Creek and its tributaries is a major contributing factor to the sharply peaked hydrographs, which are characteristic of the upper reaches of the basin. It is also a factor in sediment production. However, because much of the watershed is forested and most of the side streams are flowing over relatively hard beds, the quantity of sediment which the stream transports is not excessive. The largest concentration of suspended sediment that has been observed since periodic sampling of Salt Creek at the dam site was begun in August 1955 was 682 parts per million for a stream flow of 3,620 cubic feet per second on February 3, 1956, which would be equivalent to 6,700 tons per day for that rate of flow. The lowest concentration observed was 2 parts per million, which was too small to use in computing tonnage. The weighted average of all observations was 345 parts per million.

On the basis of the periodic sampling and studies of sedimentation rates in other reservoirs, it is estimated that Salt Creek and its tributaries will produce annually about 0.3 acre-foot of sediment per square mile of drainage area. This amounts to 88 acre-feet annually. Storage is being provided to accommodate 27,000 acre-feet of sediment, so that the operation of the reservoir will not be impaired by sediment collection for about 200 years.

This sediment inflow is comparable with the results of a U. S. Soil Conservation Service study of sedimentation in Spring Mill Lake during the 10-year period 1938-48. During that time the average annual contribution was 0.35 acre-foot per square mile of drainage area.

Flow at the dam site. - No records of the flow of Salt Creek at the dam site were collected prior to the investigations undertaken for this report.

A gaging station was established in the vicinity of the dam site on May 12, 1955, for the purpose of collecting needed information at that location. Prior to that time, the U. S. Geological Survey maintained two other gaging stations within the basin. Table VI lists these three stations, gives the extreme and mean discharges, and indicates the periods of years for which records are available.

TABLE VI

STREAM GAGING STATIONS IN SALT CREEK WATERSHED

Location	Drainage Area (Sq. Mi.)	Period of Record	Discharge (c.f.s.)		
			Mean	Max.	Min.
Salt Creek near Peerless	582	1939 - 1950	678	20,400	0.7
Salt Creek near Harrodsburg	441	1955 - Present	393	4,700	1.0
N. Fk. Salt Creek near Belmont	120	1946 - Present	135	15,200	0

The Corps of Engineers has prepared estimates of mean monthly discharges at the dam site for the period January 1930 to September 1956 for use in studying the natural flow of Salt Creek and the extent to which operation of the reservoir might alter that flow. The estimates have been based on the records obtained at the above gaging stations and the station on East Fork of White River at Shoals and are listed Table VII.

The table of estimated mean monthly discharges shows that the minimum average monthly flows are not appreciably different from the instantaneous minimum of record at the gaging station sites. The instantaneous minimum for the gaging station at Peerless was 0.7 cubic foot per second on August 18, 1940. At Belmont, there has been no flow at times in several years. The record at Harrodsburg is too short to serve as a criterion. The estimated minimum average monthly flow at the Harrodsburg site was 1 cubic foot per second in August and October 1940.

A greater variation between instantaneous and mean monthly discharges occurs in dealing with the flood flows. As estimated, the month of greatest average discharge was January 1950 when the mean was 4,300 cubic feet per second. January 1937 was nearly as high a month with an average flow of 4,240 cubic feet per second. At Peerless, the maximum of record occurred on January 7, 1949, when a peak discharge of 20,400 cubic feet per second was experienced.

TABLE VII

ESTIMATED MEAN MONTHLY DISCHARGES OF SALT CREEK
MONROE RESERVOIR DAM SITE AT MILE 25.65
(Cubic feet per second)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1930	2,448	953	609	393	140	64	37	29	39	28	28	35
1931	38	52	240	500	136	80	145	64	229	125	286	831
1932	2,128	831	408	372	211	150	495	204	178	252	667	729
1933	2,092	805	1,736	1,665	1,905	260	112	67	53	97	70	193
1934	127	65	427	296	78	163	95	86	52	47	31	66
1935	216	81	879	455	1,002	456	286	190	92	48	147	139
1936	246	428	827	820	232	620	435	236	337	214	710	139
1937	4,241	1,287	352	550	819	193	121	186	170	428	165	733
1938	381	944	1,544	1,214	410	486	403	308	69	41	115	85
1939	345	1,355	2,094	2,130	141	472	115	29	2	5	10	2
1940	8	233	263	1,917	391	70	12	1	3	1	8	90
1941	112	110	43	238	39	550	14	8	44	53	272	273
1942	233	1,171	1,048	1,173	356	290	161	26	10	2	176	307
1943	177	596	2,354	651	1,731	224	61	29	10	3	6	6
1944	29	296	824	1,999	244	35	4	16	42	5	11	35
1945	90	679	3,292	1,724	552	1,947	69	97	561	349	1,015	890
1946	496	1,296	882	167	1,349	155	22	38	4	6	91	324
1947	997	355	352	1,913	1,950	1,453	128	77	14	6	11	30
1948	380	518	981	1,235	258	35	86	34	29	10	584	1,008
1949	4,141	1,174	1,658	302	158	289	71	229	64	585	58	968
1950	4,296	2,401	1,162	1,243	890	270	23	54	324	126	920	1,165
1951	1,571	1,627	1,264	1,196	386	234	290	80	45	36	128	1,241
1952	1,238	1,572	1,405	873	334	333	136	52	52	35	38	114
1953	499	354	859	529	704	148	162	54	27	24	27	35
1954	63	99	161	333	195	126	32	32	21	27	26	67
1955	365	682	1,699	557	261	77	113	4	14	76	528	118
1956	98	1,843	811	1,060	767	610	75	62	129	-	-	-

At Belmont, the greatest flow 15,200 cubic feet per second occurred on May 24, 1952. It is believed the flood of January 1949, and possibly the flood of 1952, exceeded the 1937 flood but these floods are of less importance because they did not coincide with major floods on main stem rivers.

The average flow computed on the basis of nearly 27 years of estimated monthly figures is 483 cubic feet per second. Hence, about 350,000 acre-feet inflow could be expected in the reservoir in an average year.

Downstream channel capacity. - The channel of Salt Creek downstream from the dam site is deep, narrow and on a flat gradient. The bed of the stream is about 25 to 30 feet below the level of the adjoining flood plains, on the average, and the channel ranges between 100 and 150 feet in width.

The flood plains, which are relatively level, are subject to overflow flooding at fairly low discharges of the stream. In two short reaches, overflow begins when the discharge rate exceeds 2,700 cubic feet per second and progressively becomes more extensive as the stage increases. However, flooding does not cover widespread areas over the flood plains along the creek until the discharge reaches about 3,200 cubic feet per second.

Chemical and bacteriological quality. - Samples of the flow at Salt Creek at the dam site have been collected about twice monthly since August 1955 for analysis to determine water quality. The results of these analyses are presented in Table VIII.

Chemically, the water at the sampling station is of reasonably good quality. It is relatively low in alkalinity and hardness. Normal methods of treatment are sufficient to produce a quality satisfactory for municipal and most industrial purposes.

The level of coliform concentration appears to be indicative of the normal level for the stream. It further indicates no significant amount of sewage is discharged into the stream closer than Nashville on the North Fork.

Four samples of water, taken on November 15, 1956, at different points along Salt Creek upstream from the dam site, were analyzed to determine possible sources of coliforms. The results indicated, as surmised above, that no local source of pollution existed. The counts were all 4,300 or less per milliliter and perhaps reflect the normal for the stream. Coliform concentrations should die out in the reservoir as a result of settling in the pool.

TABLE VIII

RESULTS OF CHEMICAL AND BACTERIOLOGICAL WATER ANALYSES*
SALT CREEK AT MONROE RESERVOIR DAM SITE, 1955-56

Date of sampling	Mean dis-charge (cfs)	Hydrogen ion concen-tration (pH)	Alkalinity as $CACO_3$ (ppm)	Hardness as $CACO_3$ (ppm)	Dissolved mineral constituents (ppm)				Equivalent Nitrogen - N_2 (ppm)			Bio-chemical oxygen demand (ppm)	Turbidity	Color	Coliforms (MPN per 100 ml)	Vola-tile	Total
					Chloride (Cl)	Iron (Fe)	Sulfate (SO_4)	Silica ($Si\ O_2$)	Nitrate	Ammonia	Organic						
1955																	
Aug. 5	6.2	8.0	68	84	22	1.5	-	-	-	-	-	-	-	-	-	6	32
Aug. 16	2.9	7.3	88	97	60	-	15	-	-	-	-	-	25	-	9300	7	33
Aug. 30	1.4	7.3	110	118	97	.4	15	-	-	.08	.57	2.5	15	40	9300	9	22
Sept. 21	1.2	7.5	130	148	190	.3	15	-	-	.03	.42	5.0	18	5	3900	11	23
Oct. 5	12	7.2	50	57	17	1.3	15	-	-	-	-	1.9	150	20	9300	12	80
Oct. 14	38	8.3	44	62	11	1.3	25	7	-	-	-	1.5	40	40	4300	5	33
Nov. 4	844	6.8	28	46	4	1.8	21	7	-	-	-	4.0	250	20	-	-	292
Dec. 11	120	7.6	30	60	6	.6	25	-	-	.04	-	1.1	7	20	-	-	2
1956																	
Feb. 3	3620	6.8	12	46	0	2.5	21	-	-	-	-	-	450	50	-	44	682
Mar. 9	2150	7.2	18	180	0	.7	24	8	-	.04	1.03	-	90	30	9300	-	94
Mar. 28	374	7.4	26	50	4	-	27	-	-	.01	.89	1.0	15	20	-	6	17
Apr. 18	430	7.2	30	40	4	.5	24	-	.5	-	-	1.0	15	10	-	9	25
May 7	390	7.3	27	57	5	.7	29	-	.2	-	-	1.0	50	15	-	-	71
May 24	39	7.3	38	44	11	.7	29	-	.2	-	-	1.0	15	-	-	-	16
June 20	234	7.5	38	50	3	.9	19	-	.4	-	-	1.1	30	20	-	11	54
July 13	183	7.8	51	57	10	-	-	-	-	-	-	-	150	-	-	-	88
July 30	157	7.3	42	52	4	-	-	-	-	-	-	-	-	-	-	-	42
Aug. 27	3.4	7.4	63	79	65	-	-	-	-	-	-	5.4	60	-	-	-	20
Sept. 20	100	7.6	34	-	7	-	-	-	-	-	-	4.5	-	-	-	-	53
Oct. 18	17	7.0	67	-	61	-	-	-	-	-	-	-	-	-	-	1	9

*Chemical analyses are reported in parts per million by weight; color and turbidity by matching with standards; coliforms as most probable numbers per 100 milliliters.

FLOODS

General. - The East Fork of White River and its tributaries are subject to destructive floods with serious overflows occurring at frequent intervals. Although most of the floods causing appreciable damage are local in nature, several have occurred which have contributed to damage along the Wabash and Ohio Rivers. Severe floods may be expected at any time, but the majority occur during the late winter and early spring.

The agricultural lands adjacent to the channel of Salt Crek and its principal tributaries are frequently overflowed by floods originating in the watershed. The lower twenty-odd miles of the valley are also frequently inundated by the backwaters of floods occurring in the East Fork of White River.

Historical floods. - Newspaper accounts are the basis for comparison of floods since the settlement of Salt Creek valley and the Wabash River basin. It is known that in the years 1828, 1847, 1856, 1866 and 1875 large floods occurred. Accounts from early inhabitants led to the belief that the flood of 1828 possibly exceeded that of 1913 and that the latter may have been slightly larger than the flood of 1875.

During the current century, floods occurred over widespread areas of the Wabash basin in 1913, 1937, and 1950. Floods of greater intensity have been experienced on small watersheds in parts of the basin but have been less serious because of the small areas involved.

The flood of March-April 1913 was probably the greatest to have occurred in this region, both in volume and peak discharge. It was the result of an unprecedented amount of rainfall over the entire Wabash River basin between March 23 and 27, 1913. During this period 8.4 inches of rain fell on the East Fork of White River watershed above Shoals and produced an estimated maximum discharge of 150,000 cubic feet per second at that point. Although no discharge records are available on Salt Creek for the 1913 flood, high water marks obtained at various points along the stream establish that flood as the highest known. These highwater marks indicate the 1913 flood reached elevations of 516.9 feet at Peerless, 521.3 at Harrodsburg, and 569.3 feet on the North Fork at Belmont. The Corps of Engineers, by the unit hydrograph method, have estimated the 1913 discharge at 37,000 cubic feet per second at the dam site.

The flood of January 1937 was produced by heavy rains from January 5 to 25 falling on ground already saturated by precipitation that fell during the period December 27, 1936, to January 2, 1937. A peak discharge of 99,800 cubic feet per second in the East Fork of White River was reached on January 25, 1937, at Shoals. Serious flooding occurred in the Salt Creek valley and most extensively in the lower reaches because of backwater from the East Fork White River. Highwater marks show the 1937 flood was the second highest at the lower end of Salt Creek although the discharge rate has been exceeded by more recent floods. The Corps of Engineers has estimated that the peak discharge of the 1937 flood at the dam site was 19,700 cubic feet per second on January 15 and that a secondary crest flow was 16,800 cubic feet per second on January 22, 1937.

The floods of January and March 1950 resulted from separate intense periods of rainfall. The flood flows during these periods were of serious consequence only because they contributed to more seriously flooded conditions along the main stem of White River and along the Wabash. The peak discharge at the dam site is estimated to have been about 14,300 cubic feet per second.

Floods recorded at gages. - Information on the more recent floods has been obtained from gaging stations operated by the U. S. Geological Survey on Salt Creek near Peerless from February 1939 to September 1950 and on North Fork Salt Creek at Belmont from April 1946 to date. The annual maximum discharges for those stations and East Fork of White River at Shoals are listed in Table IX.

TABLE IX

ANNUAL MAXIMUM DISCHARGES, 1937-56

Year	E. Fk. White River near Shoals		Salt Creek near Peerless		N. Fk. Salt Creek near Belmont	
	Date	Discharge	Date	Discharge	Date	Discharge
1937	Jan. 25	99,800	-	-	-	-
1938	Mar. 21	33,700	-	-	-	-
1939	Apr. 21	56,400	Apr. 18	14,700	-	-
1940	Apr. 25	52,400	Apr. 22	12,400	-	-
1941	June 12	11,700	June 11	4,610	-	-
1942	Apr. 15	28,400	Apr. 12	7,890	-	-
1943	Mar. 23	63,500	Mar. 19	15,900	-	-
1944	Apr. 16	47,400	Apr. 13	11,900	-	-
1945	Mar. 10	74,100	Mar. 8	16,500	-	-
1946	Feb. 18	23,500	May 19, 20	5,200*	May 16	5,910
1947	June 8	40,800	June 5	10,200	June 2	10,100
1948	Apr. 17	36,900	Apr. 15	5,970	Mar. 27	3,010
1949	Jan. 10	63,200	Jan. 7	20,400	Jan. 5	13,300
1950	Jan. 10	69,100	Jan. 6	18,900	Jan. 4	11,600
1951	Feb. 26	42,700	-	-	Feb. 21	5,100
1952	Feb. 2	41,500	-	-	May 24	15,200
1953	May 21	19,900	-	-	Mar. 4	2,780
1954	Apr. 12	5,580	-	-	Jan. 27	825
1955	Mar. 6	30,600	-	-	Mar. 21	2,220
1956	June 4	34,500	-	-	May 28	3,000

*Daily discharge.

Maximum probable and standard project floods. - Even the most intense storms that have caused floods in past years could have been more severe. For example, if the storm of March 23-27, 1913, had centered over Salt Creek basin, a far greater discharge would have been experienced. For that reason it is necessary to consider much larger storms than have been experienced in the limited period for which records are available in the Salt Creek region.

The "maximum probable flood" is the estimated flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The Corps of Engineers has concluded that such a hypothetical maximum storm over Salt Creek would produce 15.3 inches of precipitation in 6 hours and 24.2 inches in 48 hours. The probable inflow into the reservoir from this storm has been determined by using the unit hydrograph method for converting the estimated effective rainfall into rates of inflow apportioned in time in accordance with the normal distribution of storm runoff characteristic of the tributary watershed. The peak inflow estimated by this method is about 266,000 cubic feet per second and the volume of runoff 522,000 acre-feet or 22.2 inches over the watershed. The flood thus derived was used as the basis for spillway design and the selection of the top of dam elevation necessary to insure structural safety under extreme flood conditions.

The "standard project flood" represents the flood discharge that may be expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably characteristic of the geographical region involved, excluding extremely rare combinations. It is used as a standard against which the adequacy of the degree of protection selected may be judged. It is general practice to use floods equal to 40 to 60 percent of the "maximum probable flood" for the same basin. The Corps of Engineers has selected 50 percent of the maximum probable flood for this project or 261,000 acre-feet and 11.1 inches of runoff.

EXTENT AND CHARACTER OF FLOODED AREA

General. - The data presented in this section of the report relates to flooding of areas downstream from the proposed reservoir and over which flood-control storage in the reservoir would exert some influence or have a beneficial effect. The total flood-plain area investigated includes about 296,300 acres of agricultural land of which about 7,800 acres lie along Salt Creek, below the dam site, 39,700 acres along the East Fork of White River, 24,100 acres along the main stem of White River and 224,700 acres in areas subject to Wabash River overflow. These areas comprise about 27 percent of the total overflow area of the Wabash River and its major tributaries and about 26 percent of the overflow area of White River and its major tributaries.

In addition to the large agricultural areas affected by flooding, portions of six towns lie in the path of floods and are subject to various degrees of inundation, and thirty-five highways and railroads cross or follow along the flood plain. Other developments, as telephone and electric transmission lines, cemeteries, oil wells, etc., are generally above all but major floods and any flooding which they may experience is of little economic importance.

To facilitate collection and presentation of data, the floodplain area has been divided into stream reaches, as shown on the general map, Plate I. These reaches are given by river-mile location in all tables presenting economic and flood damage data.

Agricultural areas. - Of the approximately 296,300 acres in the overflow area studied about 221,000 acres, or seventy-five percent, are devoted to the production of crops. The remaining twenty-five percent is in second growth timber and in uncropped land that is largely not tillable because of the frequency of inundation. The major crop planted in the flood plain is corn, with soybeans, wheat, hay, pasture and oats following in that order of importance. About seventy percent of the cultivated land is devoted to production of the cash crops of corn, soybeans, and wheat, which are well adapted to the area and produce yields in excess of both Indiana and Illinois state averages. For example, corn, soybean and wheat production exceed state average yields by about thirty-one, twenty-one and sixteen percent, respectively. The remainder of the cultivated portion of the floodplain is devoted to other crops mentioned above which are grown primarily for on-the-farm use.

Gross income from all crops during flood-free years amounts to about 18 million dollars annually, or about sixty-one dollars per acre for the total overflow area. The effects of the high crop productivity on land values is somewhat nullified by the large amount of land that is not being cultivated because of the frequency of inundation and by the amount of damage to crops in areas subject to flooding. These factors have a tendency to greatly decrease the overall desirability of the land, which is reflected in the corresponding reduction in land values. In the region studied, the land values vary from about $125 per acre in the relatively narrow, small Salt Creek overflow area to about $190 per acre in the wide, flat floodplain of the East Fork of the White and lower Wabash Rivers. The areas subject to overflow and the estimated value of land and improvements within these areas along the portions of the streams studied during the course of this investigation are summarized in Table X.

TABLE X

AREAS INUNDATED AND PROPERTY VALUES OF AGRICULTURAL LANDS WITHIN THE INVESTIGATED AREA

Stream and Reach	Location (river miles)	Area inundated (acres)	Estimated value of land and improvements
Wabash River			
Reach W-1	0.0 to 40.0	109,700	$20,820,000
Reach W-2	40.0 to 94.5	115,000	21,740,000
White River			
Reach WH-1	0.0 to 51.6	24,100	4,210,000
East Fork of White River			
Reach EW-1	51.6 to 111.9	30,900	5,472,000
Reach EW-2	111.9 to 142.9	8,800	1,517,000
Salt Creek			
Reach SC-1	0.0 to 25.6	7,800	964,000
Total, all reaches		296,300	$54,723,300

Urban areas. - There are six towns within the area under study that are subjected to various degrees of inundation. Three of these, Guthrie, Indiana (Salt Creek); Hazleton, Indiana (White River); and Maunie, Illinois (Wabash River) are rural communities with less than 500 population, providing meeting places, stores and necessary services for small surrounding areas. Large portions of these three towns are subject to inundation. Two of the other three, Shoals, Indiana (East Fork White River) and New Harmony, Indiana (Wabash River) have populations in excess of 1,000 persons, provide a large variety of services and shopping areas, and cater to a rural area greater in extent than the small rural towns. About 30 percent of the land area of Shoals and practically all of New Harmony are subject to inundation. The sixth town, Mount Carmel, Illinois, (Wabash River) is the county seat of Wabash County, has a population of about 9,000 persons and is a semi-industrialized city. The services and shopping requirements necessary to serve a large rural population are found within the city, only a small part of which is within the overflow area. All of these urban areas lie on or near railroad routes. Hazleton, Shoals, New Harmony and Mount

Carmel are on Federal and State highway routes while Guthrie and Maunie are accessible only by county road. There is given in Table XI a list of these urban areas, the type of development, and the estimated value of property subjected to inundation within each.

TABLE XI

ESTIMATED VALUE OF PROPERTY SUBJECT TO FLOOD DAMAGE
WITHIN URBAN AREAS INVESTIGATED BY THIS REPORT

Stream and Reach	Urban Area	Type of development (units)					Total value all property
		Residential	Public	Commercial	Industrial	Other	
Wabash River							
Reach W-1	Maunie, Ill.	140	7	0	4	4	$ 855,000
Reach W-2	Mt. Carmel, Ill.	212	2	6	6	6	3,468,000
	New Harmony, Ind.	357	7	45	0	8	3,830,000
White River							
Reach WH-1	Hazleton, Ind.	37	3	15	0	5	1,320,000
East Fork of White River							
Reach EW-2	Shoals, Ind.	96	4	12	0	6	853,000
Salt Creek							
Reach SC-1	Guthrie, Ind.	5	0	1	0	2	29,500
Total, all reaches		847	23	79	10	31	$10,355,500

Transportation routes. - Several important Federal and State highways and railroads cross or lie in the overflow area. Among the most important highways which, if inundated, would have an adverse effect on the economy of the nation, are U. S. 50 which crosses the East Fork in the vicinity of Bedford and again at Shoals and U. S. 41 which crosses the White River at Hazleton. Other important highways that lie in the overflow area are Indiana State Roads 37, 45, 57, 61, 64 and 66. The more important rail facilities that are subject to inundation include main lines of the Louisville and Nashville, the Chicago, Cleveland, Cincinnati and St. Louis, and the Chicago, Indianapolis and Louisville Railroads. The estimated value of all highway and railroad property within the studied area is presented in Table XII.

TABLE XII

ESTIMATED VALUE OF HIGHWAYS AND RAILROADS WITHIN THE INVESTIGATED AREA

Stream and Reach	Location (river miles)	Highways		Railroads		Total Value
		Crossings	Value	Crossings	Value	
Wabash River						
Reach W-1	0.0 to 40.0	1	$ 5,000,000	1	$1,034,000	$ 6,034,000
Reach W-2	40.0 to 94.5	2	5,026,000	2	2,469,000	7,495,000
White River						
Reach WH-1	0.0 to 51.6	2	2,169,000	1	457,000	2,626,000
East Fork of White River						
Reach EW-1	51.6 to 111.9	7	1,104,000	2	512,000	1,616,000
Reach EW-2	111.9 to 142.9	2	97,000	-	-	97,000
Salt Creek						
Reach SC-1	0.0 to 25.6	9	710,000	6	1,040,000	1,750,000
Total, all reaches		23	$14,106,000	12	$5,512,000	$19,618,000

FLOOD DAMAGE

General. - In the early part of 1956 a detailed economic and flood-damage survey of the Salt Creek overflow area was made by the Corps of Engineers to ascertain the type and extent of flood damages experienced in the area. It was found that flooding occurs almost annually in the overflow area adjacent to the streams; properties suffer extensively from crop and other losses, and transportation routes are damaged considerably by high floods. No significant amount of urban losses was found because Guthrie, the only town in Salt Creek valley flood plains, suffers little from flooding.

In conjunction with the field survey of Salt Creek, the Corps of Engineers made an investigation of the overflow areas of the East Fork of White River, White River and Wabash River that lie downstream from Salt Creek. This investigation was to ascertain what changes had taken place since the last comprehensive study was made of the overflow area in 1943-1944 (reported in House Document 197, 80th Congress, 1st Session). The investigation revealed a slight increase in area but little change in type of development has occurred. However, an increase in the use of hybrid seeds and fertilizer has raised crop production and values. Consequently, losses because of crop damage have increased.

Damages from specific floods. - The greatest flood of record in the basins of the Wabash River, White River and Salt Creek occurred in March 1913. This event inundated the entire flood plains of all those streams, causing great damage to property located therein and large indirect losses through disruption of nearly all economic activity. A damage survey was not made of this flood. However, the Corps of Engineers has estimated that, in the area studied in this report, flood damages at the time of the 1913 flood occurrence would have been about $2,300,000. Naturally, a similar flood during the crop season would have caused even greater losses.

The greatest crop season floods known to have occurred in the areas studied were those of May 1943 on the Wabash River and White River; April 1944 on East Fork of White River; and June 1945 on Salt Creek. These floods caused great crop damage and much loss of real and personal property and entailed considerable expenditures in replanting alternate crops in an attempt to recoup flood losses. It was estimated that, at the time of their occurrence, the May 1943 and April 1944 floods caused damages, within the studied area, of about $4,100,000 and $2,780,000 respectively. The 1945 flood was local in extent and caused considerable damage only in the Salt Creek overflow area. It is estimated that this flood caused damages of about $61,000.

Classes of flood damages. - Data on flood damages developed during the survey of Salt Creek and the reinvestigation of the White and Wabash Rivers were supplemented with previously obtained data and office studies to obtain the present value of flood losses. For study purposes, damages were divided into three classes: agricultural, urban and transportation route. Damages to agricultural properties were further subdivided into crop and non-crop categories, while damages to urban areas and transportation routes were subdivided into direct and indirect damage categories. Agricultural crop damages include those resulting from flooding of crops, while non-crop damages include those to structures, livestock, land, fences and all other appurtenances to agricultural pursuits. Direct damages to urban areas and transportation routes consist of all damages to buildings and their contents, structures and rights-of-way, while indirect losses consist of non-recoverable lost wages and sales, losses from detouring road and rail traffic and additional expenditures required to maintain life and services during the flood emergency.

Current estimates of tangible flood damage. - The result of the Corps of Engineers' damage study indicates that recurrence of the March 1913, May 1943, April 1944 and June 1945 floods under 1956 conditions of developments and values would cause damages of $5,298,000, $6,583,500, $4,212,900 and $70,300, respectively.

TABLE XIII

SUMMARY OF ESTIMATED DAMAGES FOR RECURRENCES OF SPECIFIC FLOOD STAGES IN 1956

Stream and Reach	Location (river miles)	Floods			
		March 1913	May 1943	Apr. 1944	June 1945
Wabash River					
Reach W-1	0.0 to 40.0	$1,155,500	$2,414,200	$1,358,900	$ 0
Reach W-2	40.0 to 94.5	3,117,800	3,773,500	2,290,800	0
White River					
Reach WH-1	0.0 to 51.6	228,400	394,800	281,800	0
East Fork of White River					
Reach EW-1	51.6 to 111.9	507,200	0[a]	214,200	0
Reach EW-2	111.9 to 142.9	143,200	0[a]	54,700	0
Salt Creek					
Reach SC-1	0.0 to 25.6	146,500	1,000	13,400	$70,300[b]
Total		$5,298,600	$6,583,500	$4,212,900	$70,300[b]

a. The flood of May 1943 caused no damage on the East Fork of White River.
b. The flood of June 1945 caused damage only in the Salt Creek overflow area.

The 1913 and 1944 floods were common to the entire study area, while the 1943 flood inundated all areas except the East Fork of White River, and the 1945 flood was limited to the Salt Creek overflow area. There is presented in Table XIII a breakdown, by reaches, of the estimated damage that would result from a recurrence of these floods. The floods discussed above are representative of all the floods that have occurred. Damages from floods such as those of 1937, 1950 and all other floods are considered in the total damage study.

Depression of property values. - The frequency and severity of inundation has caused a depressive effect on the value of lands in the overflow area. About twenty-five percent, or 75,000 acres of the total overflow area, is in second growth timber and wasteland. A large portion of this was once in crops, but land erosion and frequent loss of crops have made cultivation unprofitable. Cultivated land has also suffered a depression of property value, as frequency of inundation does not permit either crop rotation or soil betterment programs. As a consequence, property values are low as a direct result of flood damages alone.

Intangible flood losses. - Intangible flood losses to which a monetary value cannot be assessed readily are of considerable importance. Generally, floods that inundate the portions of the floodplain that are considered in this report also cause damages in the other portions of the Wabash River and White River basins. Consequently, large segments of the population of the States of Indiana and Illinois are adversely affected by such floods. Loss of life as a direct result of flooding occurs during most major floods, and deaths as a consequence of exposure and hardship are not uncommon. Other serious intangibles resulting from flooding are the breakdown in communications and public services, the increased likelihood of the contraction of contagious diseases and the general contamination that usually follows major floods.

Average annual damages. - Utilizing the data developed by field surveys and office studies, damage curves were prepared by the Corps of Engineers for each class of development within each reach. The effects of existing levees in the lower White and Wabash Rivers were considered and allowances made for their beneficial value. Unit crop damage tables reflecting damages to specific crops from flooding at different times of the year were used for developing crop damage curves, care being taken to avoid duplication of damage and to eliminate recoverable losses. Direct and indirect damage curves were prepared for urban, transportation and agricultural non-crop losses. Stage-incremental damages from these curves were combined with the comparable stage-incremental recurrence interval developed from frequency curves based upon records of all the floods observed at the various gaging stations. The resulting application of damage data to frequency made possible the computation of average annual damages. The average annual damage in the area studied amounts to $2,683,000 and is subdivided by reaches in Table XIV.

TABLE XIV

SUMMARY OF AVERAGE ANNUAL FLOOD DAMAGES

Stream	Reach	Location (River miles)	Average annual flood damages
Wabash River	W-1	0.0 to 40.0	$ 677,700
	W-2	40.0 to 94.5	1,359,300
White River	WH-1	0.0 to 51.6	205,000
East Fork of	EW-1	51.6 to 111.9	296,000
	EW-2	111.9 to 142.9	87,500
Salt Creek	SC-1	0.0 to 25.6	57,500
Total average annual damages			$2,683,000

EXISTING FLOOD CONTROL PROJECTS

General. - During the past 20 years, Congress has authorized the Corps of Engineers to construct several flood-control projects in the White River Basin. Most of these have been along the main stem of the White River, above the confluence of the East Fork, and consist of flood walls and levees in the cities of Muncie and Indianapolis and some levees for the protection of rural areas. One flood-control reservoir, Cagles Mill Reservoir on Mill Creek in Putnam County, has been constructed.

Projects downstream from Salt Creek. - No project for flood control or allied purposes for which the Corps of Engineers is responsible has been authorized or constructed in the Salt Creek watershed. Downstream from Salt Creek one project, the Brevoort Levee, has been constructed in Knox County on the left bank of Wabash River between Miles 104.5 and 127.5 above the mouth and along the right bank of White River from Mile 6.3 to 22.2 above the mouth.

A non-federal levee is located at and provides limited protection for part of the town of Hazleton on the left bank of White River. This levee, 0.4 mile in length, is about 19 miles above the mouth of White River. It was improved in 1934 by the Works Progress Administration at a cost of $7,400.

Several levee projects have been authorized by Congress for construction along the East Fork and the main stem of White River, downstream from Salt Creek, but have not been started. In general, the construction of these projects has been delayed by lack of agreement of local interests to furnish the necessary cooperation, assume damages and operate the completed works in accordance with regulations prescribed by the Secretary of the Army. These projects are as follows:

Levee Unit No. 1 - Pike County; left bank of White River; authorized 1946; protection - 6,700 acres, agricultural land; estimated cost - $1,755,000.

Levee Unit No. 7 - Knox County; right bank of White River; authorized 1946; protection - 7,000 acres, agricultural land; estimated cost - $1,210,000.

Levee Unit No. 17 - Gibson County; left bank of Wabash River between White and Patoka Rivers; authorized 1946; protection - 5,000 acres, agricultural land; estimated cost - $702,000.

Shoals, Indiana - Martin County; left bank of East Fork of White River; authorized 1936; protection - City of Shoals; estimated cost - $543,000.

IMPROVEMENTS CURRENTLY DESIRED

General. - Many improvements and flood protection projects are needed in the White River basin. These vary from flood control reservoirs to minor levee and flood wall projects. At the present time, attention is directed to a reservoir on Salt Creek. The need for this reservoir is reflected in the number of resolutions and endorsements received in recent years from people living in the Salt Creek region.

In 1949, the Indiana Flood Control and Water Resources Commission received a petition signed by 867 residents of Indiana requesting that consideration be given to the construction of a reservoir on Salt Creek to "--serve the purposes of flood control and aid in soil conservation, promote recreation, provide a source of water supply in an area which often suffers a deficiency of usable water---". This petition focused public attention on a project which had been under consideration since 1946.

Public hearings. - Although no hearings have been sponsored by the Commission specifically to permit the people of Indiana to present their views concerning the proposed Monroe Reservoir, many meetings have been organized by interested groups and have been held in the region for the purpose of discussing the reservoir plan.

In March 1954 a meeting sponsored by Southern Indiana, Incorporated, was held at French Lick Sheraton Hotel, at which time the Corps of Engineers and members of the Commission outlined the steps necessary to the development and construction of the project.

In September 1954 Southern Indiana, Incorporated, endorsed a resolution asking the U. S. Corps of Engineers to survey the possibilities of flood control reservoirs on tributaries of East Fork of White River, with particular attention to Salt Creek.

In September 1954 businessmen of Bloomington and Bedford sponsored a tour to Salt Creek Valley and the reservoir site in connection with a business meeting of the Commission held in Bloomington.

Since 1954 several meetings have been held to present data on the reservoir now under study and outline the progress of studies.

Views of local people. - The people of southern Indiana are showing a considerable interest in the development of reservoirs in the region for flood control, increasing low flow in streams, recreation, and allied uses. The East Fork of White River and its tributaries are subject to destructive floods and serious overflows occur at frequent intervals. These floods result in large agricultural losses, particularly to crops. Reduction of this flooding and concomitant damages has been a concern of the people in the region for some time. Recent droughts have highlighted the necessity for reserve water supplies. With the advent of the shorter work week and longer vacation periods, recreation is becoming increasingly more important and many people are turning to lakes and streams for relaxation. Many have urged construction of a permanent lake in the reservoir for this purpose, and have strongly recommended that the lake level for water storage purposes be placed at approximately elevation 540 so that withdrawals will not affect levels too greatly and materially reduce recreational values.

FLOOD AND RELATED PROBLEMS AND SOLUTIONS CONSIDERED

Flood problem in Salt Creek. - Salt Creek occasionally overflows its banks and causes flood damages to the areas along its valley. This damage is chiefly to agricultural lands and consists of loss of growing crops, soil erosion, sanding, fence damage, and other losses common to rural districts along floodplains. Other effects of these overflows consist of damages to public improvements such as highways, railroads and utility systems. The value of these lands and improvements to the general economy of the area precludes a consideration of abandonment or relocation as a solution. The benefits resulting from a channel improvement program would be purely local in extent and would be nullified by the aggravation of flooding downstream due to faster run out of the water within the watershed. The narrowness of the plain subject to overflows would require a high ratio of miles of levee to acres protected. Flood protection by construction of levees along Salt Creek is not justified. The construction of a flood-control reservoir would provide the best solution to the flood problems within the Salt Creek watershed and would also be beneficial to downstream areas in the reductions of crests due to the holdout and could be integrated into the comprehensive plan for flood control of the White and Wabash Rivers.

Flood problem downstream from Salt Creek. - Previous Corps of Engineers reports on the Wabash River basin indicate that the solution of many of the problems along the Wabash, White and East Fork of White Rivers could be accomplished by levee construction or improvement of existing levee units. Many of the levees along these streams protect large areas and have been maintained in excellent condition. This indicates that flood-control improvements of this type have been successful. However, these levees are sometimes inadequate and protection of smaller and submarginal areas by construction of levees is often economically infeasible. In general, the topography of the lower Wabash basin is flat to gently rolling and does not provide suitable sites for reservoirs. Owing to the many restrictions to flood flow in the lower portion of the stream from levee and bridge construction, it appears that reservoirs on upstream tributaries possibly might prove a solution, because they would reduce flood heights and would lessen the requirements of levee set-backs or alteration of existing improvements.

Prior plans considered. - Plans were prepared by the Corps of Engineers for a reservoir near Shoals, Indiana, under the authorization of the flood control plan for the Ohio River basin approved by the Congress in the 1938 Flood Control Act. The project consisted of a proposed dam across the East Fork of White River about four and one-half miles upstream from Shoals for the purpose of flood control and with provision for possible use for hydro-electric power.

Because of strong local opposition the Chief of Engineers later recommended that authority for construction of the Shoals Dam be repealed. This recommendation was adopted in the Flood Control Act of 1946. Accordingly, no authority now exists for construction of a dam and reservoir in the vicinity of Shoals.

Related problems. - In accordance with the expressed desires of local interests, the 1955 Indiana General Assembly recognized the importance of the water resources of the Salt Creek watershed by directing the Flood Control and Water Resources Commission "--to determine costs, scope of storage, relationship of water resources use, and all available benefits, and similar information relating to a proposed water supply reservoir in Salt Creek valley of southeastern Monroe County, parts of Jackson County and parts of Brown County".

The study of water resources uses directs attention to the need for storing water during periods of excess or flood flows to reduce flooding downstream and for later release of stored water particularly during periods when increases in low flow will be beneficial in reducing the degree of stream pollution, in providing additional water to the many water users downstream and in promoting the general welfare of the State.

Full development of site necessary. - The rapid growth of water requirements in the State together with the limited supplies now available make it necessary to develop the full potentialities of every site on which a reservoir is constructed. The need for additional supplies is becoming so acute that, hereafter, no reservoir should be constructed to serve a single purpose when it can be put to multiple-purpose use.

The need for additional water supplies in the future can be visualized easily by a consideration of the population trends alone. Students of population statistics have estimated that the population of the United States will reach 203.5 million by 1970 and 275 million by the year 2000. The population of Indiana is expected to follow a similar trend and to reach 5.35 and 7.20 million in those respective years. These population trends are shown in more detail in Table XV and Chart I.

TABLE XV

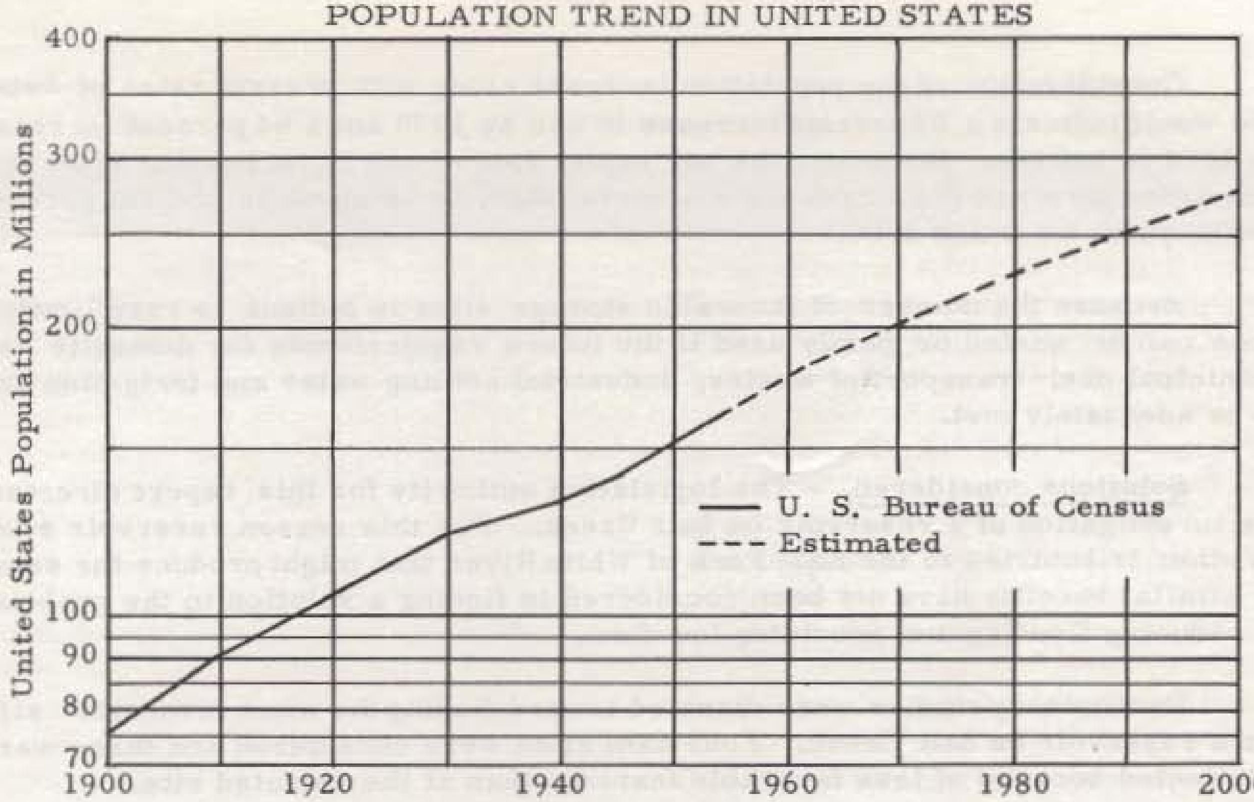
POPULATION TRENDS
(in millions)

Year	Indiana	United States	Year	Indiana	United States
1900	2.516	76.0	1960	4.69*	178.2*
1910	2.701	92.0	1970	5.35*	203.5*
1920	2.930	105.7	1980	5.98*	227.8*
1930	3.239	122.8	1990	6.59*	251.6*
1940	3.428	131.8	2000	7.20*	275.0*
1950	3.934	151.7	2010	7.80*	298.0*

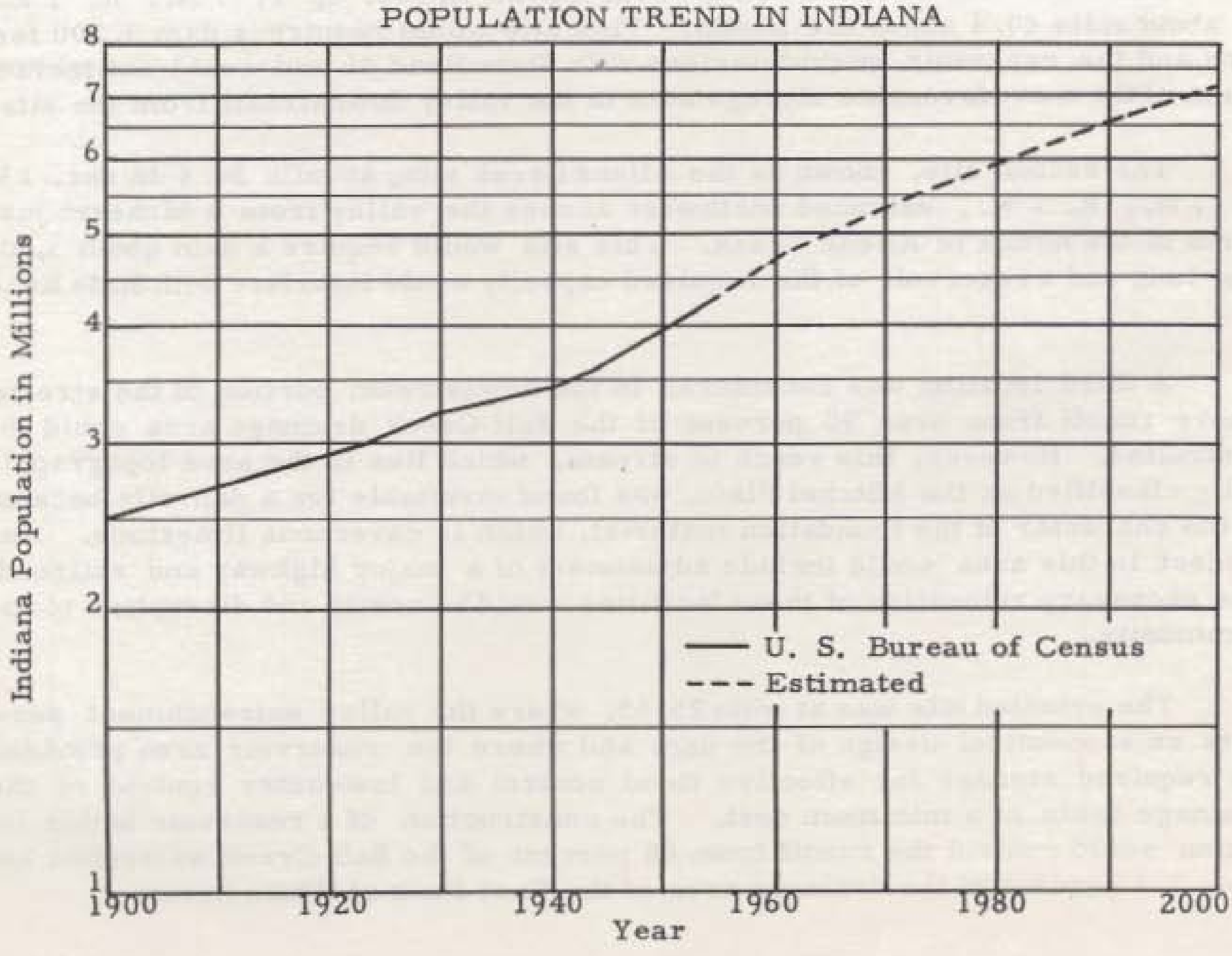
*Estimated.

CHART 1

POPULATION TREND IN UNITED STATES



POPULATION TREND IN INDIANA



Consideration of the population increase along with present rates of water use would indicate a 23 percent increase in use by 1970 and a 64 percent increase by 2000 in Indiana. However, the per capita rate of use is increasing at an accelerating pace and the increases are more likely to be about 56 and 185 percent by the years 1970 and 2000.

Because the number of favorable storage sites in Indiana is very limited none can be wasted or partly used if the future requirements for domestic and municipal use, transport of wastes, industrial cooling water and irrigation are to be adequately met.

Solutions considered. - The legislative authority for this report directed the investigation of a reservoir on Salt Creek. For this reason reservoir sites on other tributaries to the East Fork of White River that might produce the same or similar benefits have not been considered in finding a solution to the problem of reducing flooding and providing low flow.

Preliminary studies were directed toward finding the most favorable site for a reservoir on Salt Creek. Four dam sites were considered and three were eliminated because of less favorable features than at the selected site.

The first site considered was near Payne in sec. 4, T. 7 N., R. 1 E., at about mile 40.4 above the mouth. This site would require a dam 3,200 feet long and the reservoir would interfere with State Road 46 and would not include some of the more favorable storage area in the valley downstream from the site.

The second site, known as the Allens Creek site, at mile 34.4 in sec. 13, T. 7 N., R. 1 W., extended northwest across the valley from a bioherm just north of the mouth of Allens Creek. This site would require a dam about 3,600 feet long and a reservoir of the required capacity would interfere with State Road 46.

A third location was considered in the downstream portion of the stream where runoff from over 90 percent of the Salt Creek drainage area could be controlled. However, this reach of stream, which lies in the area topographically classified as the Mitchel Plain, was found unsuitable for a dam site because of the character of the foundation material, which is cavernous limestone. Any project in this area would include adjustment of a major highway and railroad. The necessary relocation of these facilities would be costly and disruptive to the community.

The selected site was at mile 25.65, where the valley entrenchment permits an economical design of the dam and where the reservoir area provides the required storage for effective flood control and low-water control of the drainage basin at a minimum cost. The construction of a reservoir at this location would control the runoff from 68 percent of the Salt Creek watershed and from 7.8 percent of the drainage area of the East Fork of White River.

MULTIPLE-PURPOSE USES

General. - Because of the large volume of storage available in this reservoir, it is possible not only to provide adequate storage for flood control, but for increasing low flow downstream and for water supply as well. The low flows of East Fork of White River and White River can be increased downstream from the mouth of Salt Creek, thereby providing additional water for domestic and municipal use, the transport of wastes, cooling for steam-electric generating stations and other industries, and possibly limited irrigation. These augmented stream flows would have even more widespread effect by contributing, in coordination with augmented stream flows resulting from other projects in the Ohio and Upper Mississippi basins, to increased flows in the lower Wabash, and in the lower Ohio and Mississippi Rivers in the interest of navigation.

Domestic and municipal use. - The present supply is adequate to meet the needs for domestic and industrial processing within the region under study. Oolitic, the only community in the Salt Creek watershed downstream from the Monroe dam site with a municipal water supply system, purchases its water from Bedford. Bedford obtains its water from the East Fork above the mouth of Salt Creek. Shoals (population 1,039) draws from wells. Petersburg (population 3,035) and Hazleton (population 498) take their water from the river, the last named for fire protection only. None of these places anticipate requiring water from the reservoir in the very near future; however, industrial growth in the region and other developments may bring about a change in the situation.

Pollution abatement. - Domestic, industrial, and municipal wastes now being discharged downstream from Salt Creek create no serious pollution problem. The present stream flow is sufficient to remove these wastes if adequate treatment is provided in accordance with existing legislation. However, the prospects of new industries along Salt Creek or East Fork of White River indicate that this situation may change in the very near future and the requirements for dilution water may materially increase.

Industrial cooling water. - No large user of industrial cooling water is presently located in the region. However, studies have been made for the establishment of one or more steam-electric generating stations along the White River below the confluence of the East and West Forks to take advantage of the coal resources of that area. Cooling water will be required in large volumes by these plants and it will be a limiting factor in their design. The region is also favorable for the location of chemical plants along the main streams, but the establishment of such plants must await increases in low water flow. The location of other new industries in the area no doubt will increase the requirements for cooling water.

Power development. - Hydro-electric power development at the dam site is not economically feasible and would be undesirable because it would not be compatible with the best operation of the reservoir for other purposes. Increases in the low flow of the East Fork of White River would be of some benefit to the hydro-electric plant at Williams except that operation of that plant is to be discontinued soon for economy reasons.

Irrigation. - With the development of portable irrigation equipment, surface water supplies are being drawn upon in considerable amounts for irrigation, particularly during droughts. The magnitude of this demand is not known in the area under consideration. So far it has not interfered with other uses of water from the streams. However, the use of water for irrigation is growing year by year and conflicts in use may be expected in the future.

Increased low flow. - Although present water uses do not overtax the supply, industrial development in the area has been retarded by lack of an abundant supply. With increased low flow downstream, industries that require large quantities of water, such as steam-electric generating stations and pulp mills, will be attracted to the area to take advantage of the abundant resources of coal and timber.

Recreation. - Generally, the valleys in the Monroe Reservoir area are well entrenched with steep wooded side slopes which have great scenic value. Benefits from recreation would be largely local in extent and any development for recreational purposes would be the responsibility of state and local governmental agencies under present federal policies for flood control projects. Incidental recreational development of portions of the reservoir area is not considered to be inconsistent with its prime purposes. However, major drawdown of the permanent pool for increasing low flow in the streams below the dam would reduce somewhat the potential recreational value of the reservoir pool; although on the other hand, increased stream flows would enhance fishing values in the streams below Monroe dam.

PROPOSED PROJECT PLAN

Monroe Reservoir. - The most favorable site on Salt Creek for a dam that would create a reservoir having adequate storage for multiple purpose uses with the least interference to established improvements was found to be at mile 25.65 above the mouth, about 1,800 feet downstream from the Harrodsburg Bridge, and about two miles east of Harrodsburg, Monroe County, Indiana. This site was selected on the basis of substantial economy of dam and spillway construction over any alternate site. The proposed reservoir pool lies in Monroe, Brown and Jackson Counties, Indiana, and the drainage area above the dam site is 441 square miles.

In addition to confining a flood equal to the maximum of record, Monroe Reservoir would provide storage for increasing low flow downstream. Low flow regulation storage available between elevations 515.0 and 538.0 is 159,000 acre-feet and is equivalent to about 6.8 inches of runoff from the drainage area. Storage below elevation 515.0 is reserved for future siltation. Flood control storage would extend between elevations 538.0 and 556.0 (spillway crest). Flood control storage capacity is 260,000 acre-feet and is equivalent to about 11.1 inches of runoff from the drainage area. The total reservoir capacity at elevation 556.0 is 446,000 acre-feet which includes a permanent pool of 27,000 acre-feet reserved for siltation. The siltation pool would inundate 3,300 acres and the maximum pool at elevation 556.0 would inundate 18,600 acres. See Plate 2 for reservoir area, and area and capacity curves.

The plan under consideration provides for construction of a dam across Salt Creek valley with outlet works along the right bank of the creek. The design of these structures has been prepared by the Louisville District, Corps of Engineers, in accordance with design criteria and policies presently employed for Federal flood control projects.

The proposed gated outlet works would have an 11-foot diameter semi-elliptical conduit with inlet invert at elevation 497.0. The outlet works would regulate discharge for flood control and low water flow which would vary with the seasons of the year. The dam has a top elevation of 578.0, a top width of 30 feet, a top length of 1,400 feet and a maximum height above the bottom of the valley of about 73 feet. The side slopes, both upstream and downstream, are 1 on 3. The embankment has an impervious earth core 20 feet wide at crest with 1 on 1 side slopes. Random rock fill is proposed on each side of the core. Five foot filter and foundation blankets are provided. Twelve-inch diameter drainage wells extending down to rock are spaced 20 feet on centers both ways. An uncontrolled saddle spillway consists of a cut through rock in the left abutment with outflow about 2,000 feet downstream from the dam. It has a base width of 300 feet at crest elevation 556.0. The approach slope of the channel is 0.5 percent and discharge slope 1.5 percent. Side slopes in rock are 4 on 1. Plate 3 shows the plan and sections for the structures.

Land acquisition. - The land to be acquired for the project will depend somewhat upon the policy adopted by the State of Indiana for development of the area around the reservoir. If the project is constructed as a Federal project without special provisions for state development, the federal policies pertaining to land acquisition for flood control projects would be followed and the land acquired in fee title would be the minimum required for proper operation of the project. If the State should plan developments around the lake for recreation and other purposes the land acquisition policy would have to be adjusted to such plans.

Under the federal policy for the acquisition of land, the reservoir plan described above would require fee title to the lands to be acquired for the construction of the dam and spillway, the access road, and all lands below a five-year flood frequency line in the reservoir area. Flowage easements would be obtained on lands between the five-year frequency and a line five feet above the flood control pool. The few improvements in the area consists mostly of houses with attendant outbuildings. Electricity is the only modern facility serving the area.

Relocations. - A county road which passes through the reservoir area in the vicinity of Payne, Indiana, would be relocated and raised to elevation 556.0. The height of fill would be about 15 feet and the length would be 0.64 mile. A new highway bridge would be provided across Salt Creek. Three miles of road north of Payne would require improvement to maintain normal traffic flow diverted from abandoned roads. Two miles of county road in the vicinity of Crooked Creek would require raising; a new bridge would be required over Crooked Creek and raising of three small bridges over tributaries of Crooked Creek would be necessary. Locations of proposed highway alterations are shown on Plate 2. Other roads no longer required will be abandoned. Plans and estimates of costs for highway changes have been prepared with the assistance of the Indiana State Highway Department. The Bureau of Public Roads, Department of Commerce, has informed the Corps of Engineers that Federal-aid highway funds are not available to defray any part of altering Federal-aid highways for proposed flood control projects when local interests are required to assume the cost of such adjustment as part of the local cooperation.

A number of power and telephone lines located in the reservoir area would be relocated where necessary to maintain existing service. There are no railroads affected. All buildings would be removed from the reservoir pool. There are three cemeteries that appear to be above the reservoir taking line and little if any damage from reservoir flooding would occur. There may be a few small family burial plots that would require relocation.

ESTIMATES OF FIRST COST AND ANNUAL CHARGES

Estimates of first cost, multiple-purpose reservoir. - The total estimated first cost of the proposed multi-purpose reservoir for flood control and increasing low flow based on July 1956 price levels is $9,500,000. Estimated first costs are summarized in Table XVI and include contingencies.

TABLE XVI

SUMMARY OF FIRST COSTS FOR MONROE RESERVOIR

Feature	Amount
Dam and appurtenances	$3,526,000
Reservoir and pool preparation	838,000
Relocations	961,000
Buildings, grounds and utilities	120,000
Access road	72,000
Land and damages	3,000,000
Sub-total	$8,517,000
Engineering and design	500,000
Sub-total	$9,017,000
Supervision and administration	483,000
Total estimated cost (July 1956)	$9,500,000

Estimates of annual charges, multiple-purpose reservoir. - Table XVII presents a summary of investment costs and annual charges for the proposed multi-purpose reservoir. A construction period of three years has been used to compute interest charges during construction. Estimated value for resale of the reservoir area purchased by fee simple title has been deducted from the gross investment. Interest rate is 2.5 percent and the reservoir project net investment has been amortized over an assumed life of 50 years at this interest rate. The net investment is $9,196,000 and the total estimated annual charges are $376,000.

TABLE XVII

ESTIMATED INVESTMENT COSTS AND ANNUAL CHARGES FOR MONROE RESERVOIR

Item	Amount
Investment	
Total first cost	$9,500,000
Interest during construction	356,000
Gross investment	$9,856,000
Less salvage value (lands)	660,000
Net investment (July 1956)	$9,196,000
Annual charges	
Interest	$ 246,400
Amortization	94,600
Maintenance and operation	35,000
Total estimated annual charges	$ 376,000

ESTIMATES OF BENEFITS

General. - Benefits that will accrue to the proposed plan of improvement consist principally of those from water stored in the reservoir for increasing the low water flow of East Fork of White and White Rivers and flood control benefits that will result from the reduction in flood stages and durations downstream from the reservoir site.

Flood control benefits. - Flood control benefits provided by the proposed Monroe Reservoir, as computed by the Corps of Engineers, consist of the annual value of the reduction in flood damages that will result from operation of the reservoir. Annual damages were derived for both present and future conditions of inundation by use of the stage damage-stage frequency method of obtaining average annual damages. The differences in average annual damages between the present flooding conditions and the modified conditions resulting from operation of the reservoir are creditable to the reservoir as flood prevention benefits.

A small amount of development has taken place in the floodplain in the past decade and it is anticipated that this growth will continue throughout the life of the project. It is estimated that at the end of fifty years the value of this development will have added about twenty-five percent to the existing development in the floodplain. Consequently, flood control benefits have been increased by twelve percent to allow for this growth. The estimated flood control benefits creditable to the proposed project for the areas within the Wabash River basin are presented in Table XVIII.

TABLE XVIII

ANNUAL FLOOD CONTROL BENEFITS

Stream	Reach	Location (river miles)	Average annual flood control benefits
Wabash River	W-1	0.0 to 40.0	$ 34,000
	W-2	40.0 to 94.5	77,000
White River	WH-1	0.0 to 51.6	18,000
E. Fk. White River	EW-1	51.6 to 111.9	53,000
	EW-2	111.9 to 142.9	15,000
Salt Creek	SC-1	0.0 to 25.6	63,000
Annual flood control benefits			$260,000

Benefits credited to reduction in flooding on the Ohio and Mississippi Rivers were computed by assigning a monetary value to the effective reduction in discharges on the two streams resulting from reservoir holdout. Ohio River holdout was derived by routing six representative floods from the reservoir through intervening reaches to the Ohio River and using the average holdout of these floods as the annual holdout. Benefits to the Mississippi River are based on the reservoir holdout on the maximum flood of record, that of March 1913, as routed to Cairo, Illinois, and is equivalent to the current annual value of the reduction in construction costs of Mississippi River flood control works made possible through the operation of the Ohio River comprehensive reservoir plan. The benefits assigned to the reservoir, from reduction of flood discharges on the Ohio and Mississippi Rivers, are $24,000 and $108,000 respectively.

Higher land utilization benefits. - The existing flood situation has resulted in a depression of property values from both a decrease in income from flood losses and a loss of income producing land which has been allowed to revert to wasteland because of the frequency of inundation. Although all lands studied in this report will benefit through the reduction of flood stages and durations, it is believed that only the land on Salt Creek that lies immediately downstream from the reservoir will benefit to the extent that a firm estimate of higher land utilization benefits can be made. Based on field surveys it has been ascertained that lands lying below the present four-year flood of Salt Creek would be benefited considerably by the reservoir. Areas above this four-year flow line are more intensely cultivated, contain less acreage of woods and wasteland, and have experienced a lesser depressive effect, than below this flow line. Consequently, the area considered for these benefits has been limited to the area up to the four-year flood. The monetary value of higher land utilization benefits was established by the Corps of Engineers by ascertaining the annual increase in income that will result from the improvement, and subtracting the annual cost of conversion of presently unproductive land and the increased costs necessary to produce the greater income. Higher land utilization benefits that will accrue to the Salt Creek overflow area are estimated to average $6,000 annually.

Increased low flow benefits. - The increases in low flow downstream from Monroe Reservoir will prove of great value to southern Indiana and the State as a whole, as it will encourage the development of industries along the lower reaches of the East Fork of White River and White River. Coal in large quantities, suitable for steam-electric power generation, is found in the southwestern corner of the State; large stands of timber across southern Indiana, ready for harvest, can provide lumber products, pulp and paper, and charcoal and its by-products; great quantities of high-quality limestone are available for use in a wide diversity of items, including cement; and large deposits of gypsum are now being opened up for the manufacture of plasterboard and related materials. Industries using these resources will need water in large quantities.

The most apparent uses for an increased supply of water in the near future are for cooling water for steam-electric power generation and dilution water for abating pollution from waste products from wood pulp mill operation, chemical plants or other industries.

Steam-electric power generation requires such large volumes of water for condenser cooling that the availability of water is a limiting factor in determining plant size. Many of the existing plants in Indiana can be built no larger without the use of expensive towers for cooling and recirculating water. Other plants have protected themselves by installing cooling towers for emergency use during the more severe dry periods.

With present plant sites being used to practical limits, additional power generating capacity must be located at new sites. Important factors in selecting sites are: (1) adequate supply of water for cooling purposes, (2) convenient coal supply, and (3) favorable location with respect to the power market.

The trend in plant size in recent years has been toward larger and larger installations. The use of one large rather than several smaller plants permits economies in buildings, equipment installations and labor force. The use of large generating units is now more feasible than formerly and individual unit sizes are approaching 500,000 kilowatts. Power company engineers agree that new plants should be thought of in terms of capacities of 1,000,000 kilowatts or more. Plants of this size require approximately 1,100 to 1,800 cubic feet per second of cooling water without the use of cooling towers or other supplemental cooling arrangements, and use approximately 3,000,000 tons of coal annually.

In selecting a favorable site for a 1,000,000 Kw power plant the water requirements will indicate that the Ohio River and Wabash River below Riverton are the only streams that have large enough sustained low flows in Indiana. For larger plants the Wabash would not be large enough above the mouth of White River.

The most convenient location in relation to coal supplies is in the coal mining region where a minimum of transportation of coal would be required. The coal-producing region in Indiana is located in the southwestern part of the State and is convenient to the Wabash River from Covington to its mouth and to the lower reaches of the East and West Forks of White River and White River. The same area is also convenient to the coal-producing regions of Illinois and Kentucky.

The determination of a favorable location with respect to power market is beyond the scope of this report, but it would be influenced by the need of each power company to balance its load distribution areawise, by cost of transmitting power over long transmission lines in comparison with higher coal transportation costs with shorter transmission lines and by other factors.

The White River below the confluence of the East and West Forks is favorable for plants of about 600,000 Kw capacity and can be made favorable for larger plants by increasing the minimum flow in the stream. Such increases in low flow can be made possible by releases from the proposed Monroe Reservoir.

A growing population, increased use of year-around home air-conditioning, greater automation in industry, and a general increase in manufactured products of all kinds will require increasing amounts of electric energy in the years ahead.

The use of electric energy is growing at a fantastic rate. The Federal Power Commission reports that the production of electric energy by utilities in the United States in 1955 was 547.0 billion kilowatt-hours and has estimated that the production rate will be up to 1,173.2 billion kilowatt-hours in 1970 and 1695.5 in 1980. Estimates by the Electrical World, an electrical industry trade magazine, estimates much higher rates, predicting a production of 1700.1 billion kilowatt-hours by 1970.

TABLE XIX

ELECTRIC ENERGY PRODUCTION IN UNITED STATES
ALL UTILITY SYSTEMS
(Energy in Billion Kwh, Capacity in Million Kw)

Year	Federal Power Commission		Electrical World	
	Energy Production	Capacity	Energy Production	Capacity
1920	39.4	12.7		
1925	61.5	21.5		
1930	91.1	32.4		
1935	95.3	34.4		
1940	141.8	39.9		
1945	222.5	50.1		
1950	329.1	68.9		
1955	547.0	116.3		
1960	754.5	170[a]	811.9	175.3
1965	956.5	216[a]	1175.8	251.7
1970	1173.2	264[a]	1700.1	360.3
1975	1419.5	319[a]	2300[a]	490[a]
1980	1695.5	380[a]	3100[a]	660[a]
1985	2000	450[a]	4100[a]	873[a]
1990	2310	520[a]	5450[a]	1160[a]
1995	2650	596[a]	7050[a]	1500[a]
2000	3000	675[a]	9000[a]	1920[a]

Actual figures shown through 1955.

a. Projections by Flood Control and Water Resources Commission

CHART 2

ENERGY PRODUCTION AND CAPACITY OF ALL UTILITY SYSTEMS
UNITED STATES

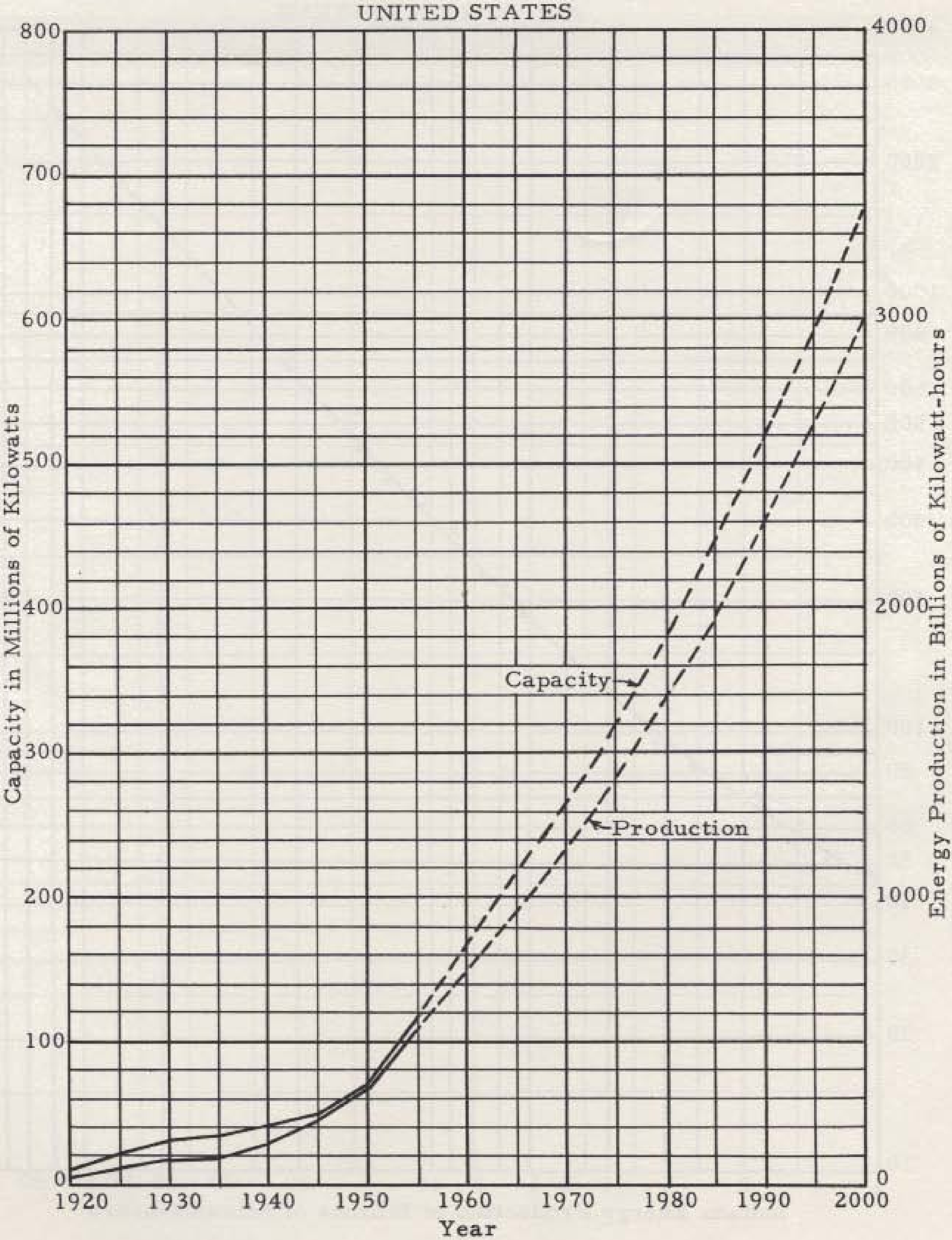
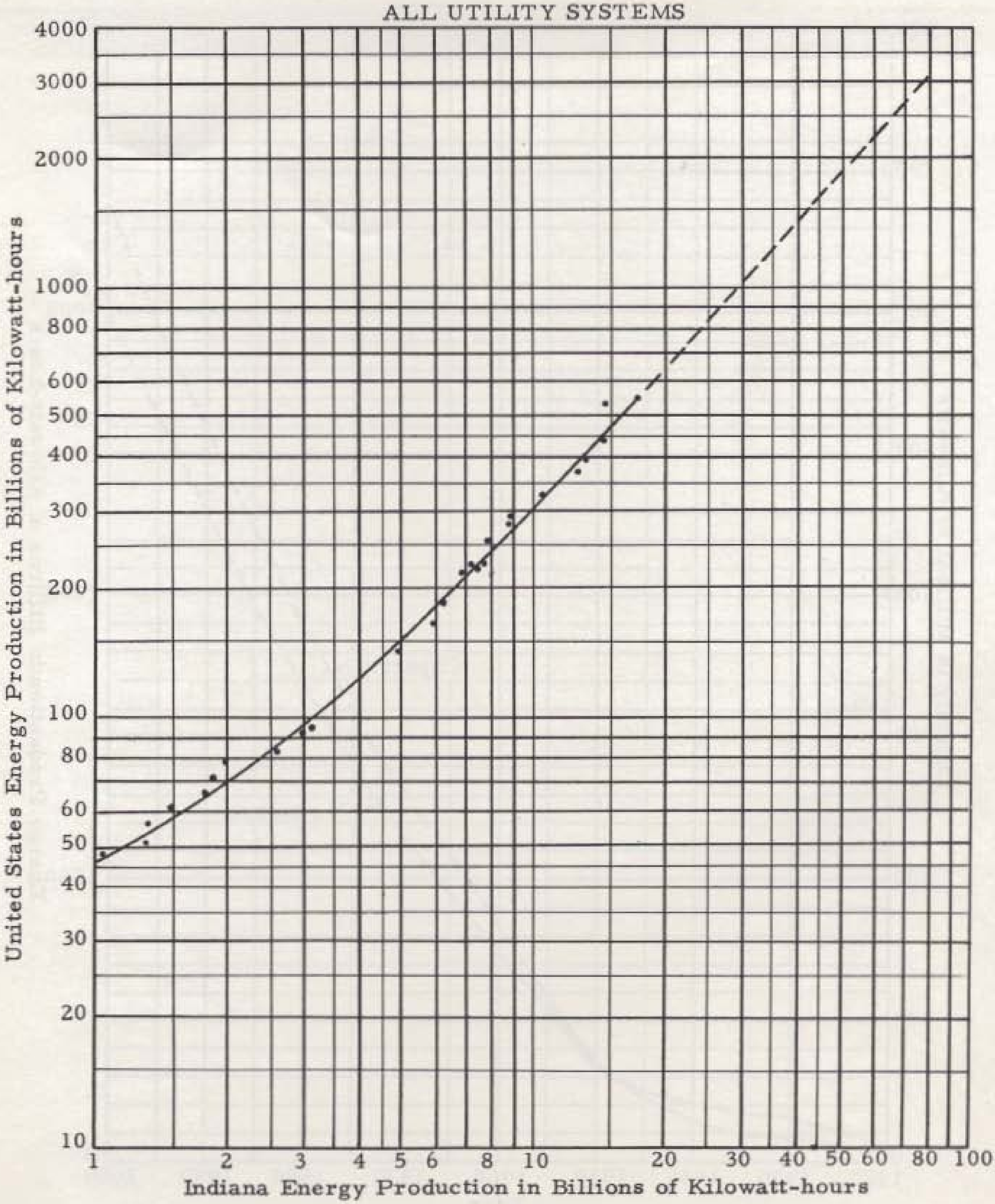


CHART 3

RELATIONSHIP OF ELECTRIC ENERGY PRODUCTION
IN INDIANA AND UNITED STATES
ALL UTILITY SYSTEMS



Past production with estimates for the future in the United States are tabulated in Table XIX and shown graphically in Chart 2. The estimates have been projected to the year 2000 to furnish some indication of what may be expected during the economic life of the project.

The estimates of the Federal Power Commission are conservative and in the past have been under later actual production. The estimates of the Electric World are based on the assumption that the increase in electric energy production will continue at its present exponential rate.

Because similar forecasts for Indiana are not available, a comparison of Indiana energy production has been made with that of the United States to establish a relationship, which is shown on Chart 3. The relationship was then used to make estimates of Indiana electric energy production to the year 2000. The plant capacity required in millions of kilowatts was then determined by multiplying the annual energy production in billions of kilowatt-hours by a factor of 0.213. The results of these computations are tabulated in Table XX and shown graphically in Chart 4.

TABLE XX

ELECTRIC ENERGY PRODUCTION IN INDIANA
ALL UTILITY SYSTEMS
(Energy in Billion Kwh, Capacity in Million Kw)

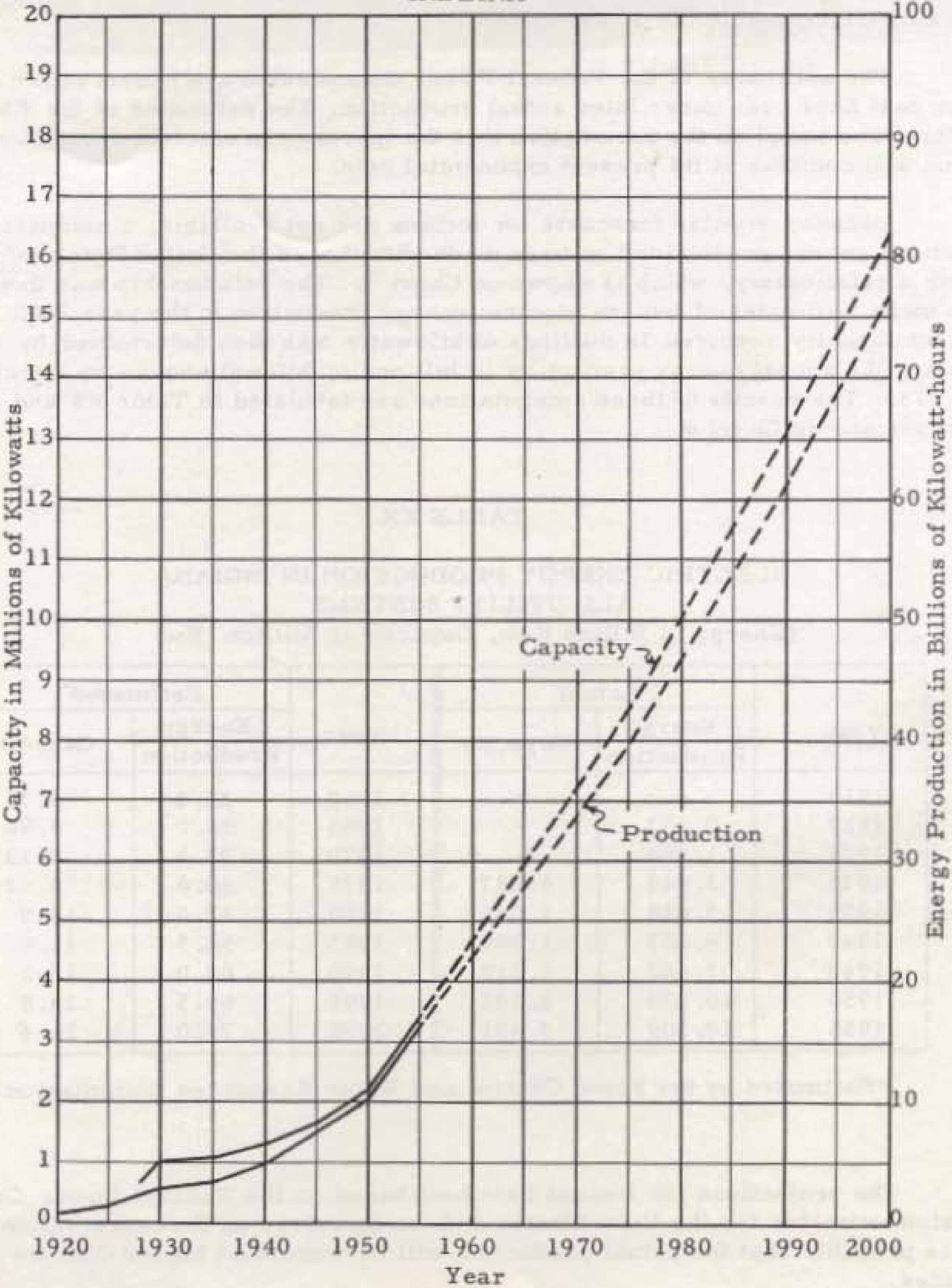
Year	Actual		Year	Estimated*	
	Energy Production	Capacity		Energy Production	Capacity
1910	-	-	1960	22.3	4.75
1920	0.933	-	1965	28.0	5.96
1925	1.484	-	1970	33.5	7.13
1930	2.943	0.987	1975	40.0	8.52
1935	3.048	1.041	1980	47.0	10.0
1940	4.883	1.289	1985	54.5	11.6
1945	7.442	1.610	1990	62.0	13.2
1950	10.374	2.142	1995	69.5	14.8
1955	17.309	3.451	2000	77.0	16.4

*Estimated by the Flood Control and Water Resources Commission.

The projections for Indiana have been based on the Federal Power Commission estimates for the United States and are therefore on the conservative side. It is probable that the actual production will be somewhat higher than the estimates.

CHART 4

ENERGY PRODUCTION AND CAPACITY OF ALL UTILITY SYSTEMS
INDIANA



The figures in Table XX show that by 1970 the production of electric energy in Indiana will be about twice what it was in 1955 and that by the year 2000 it will be 4.5 times that amount. This will mean that generating capacity will have to be increased 3.7 million kilowatts by 1970 and 13 million kilowatts by the year 2000 above the 1955 figure.

In terms of plants this will mean better than three 1,000,000 kilowatt plants in the next 14 years or approximately one every four years. The rate of installation will then have to be increased to about one 1,000,000 kilowatt plant every 3.5 years to meet the requirements by year 2000.

The location of all these plants will be a critical problem. Water in sufficient quantities can be obtained along Lake Michigan, the lower Wabash and the Ohio. It is only along the Ohio, lower Wabash and White Rivers that coal is also readily available. It is certain that these streams will furnish the sites for many of the future power plants.

With the White River low flow increased, the stream can become a favored location for two or more of these plants. Without an improvement in the low flow the river will be suitable only for the development of plants of smaller capacity, or of larger plants with much higher installation and maintenance costs.

Two companies in their quest for new generating station locations have seriously considered sites on the White River near Petersburg. Coal is readily available, but inadequate water supplies for the size of station each contemplates, plus the high cost of constructing and maintaining transmission lines to load centers, have weighed against development of these sites at the present time.

With respect to the natural flow of White River, the largest generating station that might be constructed now, without supplementary cooling arrangements, would be 600,000 kilowatts. If the flow were to be increased by releases from storage to 1,400 cubic feet per second in the summer and to 1,000 cubic feet per second during the remainder of the year the size of the plant could be 1,300,000 kilowatts.

To obtain this capacity in a plant using a combination of natural stream flow and cooling towers would entail an additional expense of $5,345,000 for the towers, plus an annual operating expense of $138,000, according to power company estimates.

It is probable that a plant of 1,300,000-kilowatt capacity would not be placed in operation before 1970, allowing time for completing already scheduled plant additions to the utility systems, and planning, design and construction of new plants.

The earliest date at which Monroe Reservoir might be completed is 1960. By allowing a 50-year economic life for the project, the time during which costs and benefits must be evaluated would extend to the year 2010.

If Monroe Reservoir is constructed to include the function of increasing the low flow of East Fork of White and White River, the need for cooling towers will be eliminated with resultant savings that will be creditable as benefits for including that feature in the reservoir.

To establish the annual value of this saving it is assumed that the reservoir will be put in operation in 1960 and that a minimum of two generating plants will be built, each requiring cooling towers, the first plant to be put in operation in 1970 and the second in 1985. As the life expectancy of a cooling tower is 25 years, it will be necessary to replace the cooling tower for the first plant in 1995.

Because the power plants will be put in operation at varying times after the reservoir is built, they will not receive full time benefits from the provision of increased low flow from the reservoir. To distribute the benefits equally over the economic life of the reservoir, computations have been made on the basis of an annuity for each cooling tower and for replacement of the first tower, the value of which is the present worth (1960) of the cost of the towers when they are put in operation. The present worth of these annuities was then amortized with interest over the 50-year life of the reservoir. The annual value of these first costs with the prorated annual cost of operation and maintenance are benefits attributable to the increased low flow. Computation of these benefits are presented in Table XXI.

TABLE XXI

COMPUTATION OF INCREASED LOW FLOW BENEFITS

Item	Present value of annuity (1960)	Annual cost
First cost		
1. Annuity which has a value in 1970 of \$5,345,000 - first cooling tower	\$3,611,000	\$168,000[a]
2. Annuity which has a value in 1995 of \$5,345,000 - replacement of first cooling tower	1,355,000	63,000[a]
3. Annuity which has a value in 1985 of \$5,345,000 - second cooling tower	2,005,000	93,000[a]
Total annual first cost		\$324,000

TABLE XXI (Cont'd.)

Item	Present value of annuity (1960)	Annual cost
Operation and maintenance cost		
1. First cooling tower and replacement - annual cost of $138,000 for 80 percent of project life		$110,000
2. Second cooling tower - annual cost of $138,000 for 50 percent of project life		69,000
Total annual operation and maintenance cost		179,000
Total annual costs (benefits)		$503,000

a. Present value amortized over 50-year life of project.

The total annual saving of $503,000 accruing from reduction in generating station first costs, operation and maintenance are only the tangible benefits resulting from an increase in low flow and do not include many intangible benefits, such as increased employment, stimulation of business, etc.

Generating stations located along White River will supply power to the industrial centers of the central and northern parts of the State as well as to the southern region. Benefits from any savings in production costs will therefore accrue to the State as a whole.

Local benefits will result from increased payrolls, larger use of local resources, and increased tax payments. Some appreciation of the impact of a large plant on the local economy may be gained from the following approximate estimates for a generating station of 1,300,000 kilowatt capacity:

Cost of plant	$175,000,000
Annual coal use (tons)	4,000,000
Operating payroll	$ 1,200,000
Number of employees	200
Annual state taxes	$ 66,000
Annual county taxes	$ 245,000
Annual township taxes	$ 88,000

The effect of the above data has not been evaluated in terms of benefits to the project but should be considered as providing part of the intangible benefits.

Pulp wood and paper plants are in another field of industry that requires large supplies of water as well as a readily available source of raw material. The area around the Monroe Reservoir site and for some distance downstream will be particularly favorable for such plants if sufficient water is made available. Among the most heavily forested counties in the State are Brown, Owen, Monroe, Lawrence, Orange, and Martin, which are all within easy reach of East Fork of White River and Salt Creek.

Wood pulp is rapidly becoming a major forest product. The great increase in the use of cardboard for packaging, soft-fiber papers for toweling, and coarse-fibered felts and insulating boards for building construction has caused the demand for wood pulp to triple in the last twenty years.

The principal problem of the pulp wood industry is the disposal of wastes. Mills vary in their water requirements, depending to a great extent on the nature and degree of treatment given the wastes before they are discharged into the streams. A report on pulp manufacturing factors, prepared by the Forest Products Laboratory, Madison, Wisconsin, December 15, 1954, indicates a demand of approximately 1,000 cubic feet per second of water for the disposal of wastes from a 200-ton semi-chemical pulp mill without recovery of wastes from spent liquors.

The principal direct benefit to be gained by the construction of a pulp mill in Indiana is a marked saving in freight costs. Pulp wood now being harvested in southern Indiana is being shipped to Ohio at a cost of approximately $4.50 per cord. The companies recover a part of the cost by paying less for the wood at the loading docks, pulp logs in Indiana bringing about $2.00 less per cord than do those in Ohio, close to the mills. On this basis, a 200-ton pulp mill in Indiana, using 200 to 300 cords of pulp wood per day, would return to the sellers $2.00 more per cord, or approximately $100,000 to $150,000 per year as a benefit.

The water requirements for alleviating the pollution problem from a 200-ton mill could be met only on the White or lower Wabash Rivers where present low flows could be increased sufficiently by releases from Monroe Reservoir. The water for this purpose would be the same that might be released to provide adequate water for electric power generation and would thus serve more than one purpose.

By increasing the low flow of White River to maintain 1,000 to 1,400 cubic feet per second, the low flow of East Fork of White River could also be increased to maintain a minimum flow of 500 cubic feet per second at Shoals. This increased flow would make it possible to locate a smaller pulp wood plant, such as a 100-ton mill, farther upstream and nearer the center of timber production.

At the time of preparation of this report it was not possible to obtain from wood pulp or paper manufacturers indications as to when wood pulp or paper mills might be located on the East Fork of White or White Rivers. Lacking a reasonably firm date for such installations, it is not practical to compute benefits from this source for use in evaluating the worth of Monroe Reservoir.

Chemical plants require large quantities of water for cooling purposes and for the dilution of waste products discharged into streams. Water for these purposes can well be the deciding factor in making an otherwise favorable plant site acceptable to a chemical manufacturer.

Recent inquiries from chemical firms about the water available in East Fork of White and White Rivers lead to the conclusion that the region is favorable for some types of chemical manufacture if water in sufficient quantity can be provided. At least two of the inquires have indicated that a minimum flow of 400 cubic feet per second in the East Fork of White River would be required to support plant operations on the scale desired.

If the low flow at Shoals is increased to 500 cubic feet per second by operation of Monroe Reservoir, the needs of these plants can be more than met. Although this use of water from the reservoir would provide additional benefits to the project, the date of establishment of chemical plants in the region is not firm enough at the present time to credit such benefits to the reservoir.

Recreation benefits. - The value of recreational development around and on Monroe Reservoir is probably best determined by a study of the increase in wealth which it will produce. This increase in wealth will result from (1) the development of lands adjacent to the reservoir for homes, summer cottages, and service areas for fishing, boating, hunting and other recreation, (2) public use of the lake for boating, fishing, hunting, swimming and other water sports.

Land development might take one of three possible courses.

a. Purchase by the State of all land surrounding the reservoir which would then be preserved in a natural state of woodlands and water in which rural beauty and the cultivation of wild-life would be primary consideration

b. Purchase by the State of all lands around the reservoir followed by development of swimming beaches and picnic areas in favorable locations, and the leasing of cottage sites under suitable regulations.

c. Limited acquisition by the State of land bordering the lake, leaving the remainder of the bordering area for private development under adequate zoning regulations to protect property values and to provide safeguards against sanitary and health hazards.

Any form of development must take full recognition of the fluctuating level of the lake. All buildings must be above the maximum flood pool and facilities provided for handling boats when the pool rises during floods or is greatly drawn down by releases to supplement stream flow during periods of drought.

The great difficulty in obtaining water from wells and in disposing of sanitary wastes by septic tanks in this region may require group development of cottages in the area in order that central water supply and sewage treatment facilities may be provided.

Facilities that might be developed around the lake would be privately operated public beach areas, restaurants, overnight and weekly rental cottages, hotels, marinas, grocery stores, gas stations, and all the other services requisite to water recreation.

Benefits from recreational values will consist of the land enhancement the value of improvements placed on the land, new business, and the intangible benefits derived from pleasure and relaxation that will be made possible by the lake.

The land-enhancement values would be offset somewhat by the cost of constructing service roads and putting in other necessary facilities. Any residual benefits remaining are indeterminate at this time and cannot be computed until some layout of the subdivisions has been made and the development costs estimated.

The monetary returns to the State and to local governments from taxes on higher property values and new businesses, plus greater employment and a general improvement in the economic condition of the area as a result of the recreational value of the lake, are somewhat intangible and have not been estimated. However, such returns will be large within a few years after the lake is placed in operation.

The fluctuating level of the lake resulting from the use of the reservoir to control floods and increase low flow downstream will not be compatible with the fullest use of the lake for recreational purposes and will tend to limit and slow some developments.

The normal pool level found to be most favorable for all uses of the reservoir is at elevation 538 and that elevation has been used in this report as a basis for computing the storage capacities available for flood control and increasing low flow. Variations in pool level will occur during flood periods, when elevation 556 may be reached in the most extreme floods, and during drought periods when the reservoir may be drawn down as low as elevation 523 for the purpose of increasing stream flow downstream.

A study of past records to determine the effects of reservoir regulation on lake levels revealed that if the reservoir had been in operation during the sixteen year period 1939-55 the flood storage periods would usually occur during the winter and early spring months and would seldom extend past the month of June. During that period only the 1945, 1949 and 1950 floods would have raised lake levels more than 10 feet above normal pool level. The 1950 flood was the only one that would have raised the lake to spillway level at elevation 556.

Only four times during the summer recreation months of June to September would the lake level have been lowered more than two feet below elevation 538. The drought years of 1940-41 would have caused lowering of the pool to elevation 533 in September 1940 and to elevation 526 in September 1941. The drought of 1953-54 would have caused lowering of the pool to elevation 534 in September 1953 and to elevation 526 in September 1954. The maximum drawdown usually occurs in November and December after the peak of the recreation season.

Excepting the four years mentioned above all other years would have had lake levels lowered less than two feet below elevation 538, and during the eight consecutive years 1945 to 1952 the pool would have been lowered less than one foot during the summer months. Such regulation will not be found particularly detrimental to summer recreational use of the lake when considered in comparison with a normal seasonal fluctuation in level of about two feet for most uncontrolled natural lakes.

The recreational benefits of the reservoir fall into the class of intangibles that are not evaluated in monetary terms in this report and, therefore, are not used as creditable benefits in the comparison of costs and benefits for economic justification of the project.

Public health benefits. - The Indiana State Board of Health and the Indiana Stream Pollution Control Board were consulted in regard to the need for increased low flow for public health and sanitation purposes and the benefits that might result from operation of the reservoir for such purposes. Those agencies stated that "continued development of sprinkler irrigation together with increased municipal and industrial usage may require that additional treatment be provided for sewage and wastes above the degree of treatment now required if provision for low flow augmentation is not undertaken. The opportunities for expansion and development for industries that require large amounts of water for processing or dilution of treated waste effluents are limited by the available water supply." It may be concluded that in the future there would be definite and appreciable savings in the cost of treating sewage and industrial wastes to meet acceptable sanitary and public health standards if adequate flow is provided in the streams for dilution purposes.

Intangible benefits. - Many benefits on which a monetary value cannot be placed would accrue as a result of the construction of Monroe Reservoir. The reservoir through the reduction in flood stages and duration would increase the safety and well-being of the population of the area by decreasing the possibility of epidemic diseases, reduce the hazard of possible loss of life, and increase the overall security of the area.

By increasing the dependable low flow of streams, new businesses and industries would be attracted to the region. The increase in payrolls would stimulate existing businesses and create a need for new enterprises to serve increased populations. Increased tax returns will provide many public improvements, particularly in schools and roads.

Detriments to overland transportation. - Acquisition of flood control pools and flowage rights will produce a change in need for highway facilities. The proposed plan of highway relocations and alterations would maintain normal traffic flow in the vicinity of the reservoir. Certain other roads left in place will serve areas in the flood control pools where flowage rights will be required and where the owners may continue cultivation. Still other roads which are infrequently used may be closed temporarily during flood operations, depending on the height of water in the reservoir. Rerouting traffic during such operations will cause little inconvenience, and only for short periods of time. There will be no isolation of inhabitants in the area at any time resulting from reservoir construction or operation. The effect of permanent or periodic closure of county roads will be of relatively minor significance. Roads affected by the project and alterations to the existing road system as proposed in this report are shown on Plate 2.

Summary of tangible benefits. - The benefits being credited to this project for establishing its justification, have been limited to those for which monetary valuations can be determined by established and well recognized methods and for which there is reasonable certainty that they will take place as estimated. The tangible creditable benefits consist of the flood control benefits on Salt Creek, East Fork of White, White, Wabash, Ohio and Mississippi Rivers, the higher land utilization benefits along Salt Creek and the increased low flow benefits on White River resulting from use of water for cooling purposes by electric generating stations. Although use of water for other purposes is reasonably certain, the time at which it will be brought into use is not well enough established to provide a basis for determining tangible benefits.

The estimated tangible benefits that would accrue to the Monroe Reservoir are summarized in Table XXII. These average annual benefits total $901,000.

TABLE XXII

SUMMARY OF TANGIBLE AVERAGE ANNUAL BENEFITS CREDITABLE TO MONROE RESERVOIR

Item of benefit	Value of benefit
Flood prevention benefits	
Salt Creek, East Fork White, White and Wabash Rivers	$260,000
Ohio River	24,000
Mississippi River	108,000
Total flood prevention benefits	392,000
Higher land utilization benefits	6,000
Increased low flow benefits	503,000
Total benefits	$901,000

ECONOMIC JUSTIFICATION

General. - To be sound, the justification of any project for the development of the water resources of the state must be based largely on economic considerations. Need, desirability, enjoyment and other factors may weigh heavily in making a project attractive, but their benefits are usually intangible and not capable of being expressed in terms that can be compared directly with the cold facts of cost of a project.

Because of the difficulty in placing a monetary valuation on the tangible and more illusive benefits and to eliminate fantastic claims for them, it is standard practice to compare only the evaluable benefits with the costs for economic justification. The intangible benefits may then be used as reasons for making a project desirable and advisable as well as justifiable.

Comparison of benefits and costs. - The economic feasibility of Monroe Reservoir was determined by a comparison of costs of the project, including construction, operation, maintenance and damages, with the monetary evaluation of the benefits to be derived from its operation. For the purpose of making these comparisons and for allocation of costs to the separate uses of the reservoir, estimates of costs have been made for a single-purpose reservoir for flood control, a single-purpose reservoir for increasing low flow and for a dual-purpose reservoir. The Corps of Engineers has estimated that the annual charge would be $279,000 for a single-purpose reservoir for flood control and $269,000 for a single-purpose reservoir for increasing low flow. The annual charge for a dual-purpose reservoir serving both purposes would be $376,000.

It is found that reservoirs for either single or dual purposes are economically justified but that a dual-purpose reservoir will provide economies in construction and operation and will bring a much larger return for each dollar spent. The ratios of benefits to costs for the various types of projects are given in Table XXIII.

TABLE XXIII

COMPARISON OF ANNUAL BENEFITS AND COSTS

Item	Annual Benefits	Annual Benefits	Ratio Benefits to costs
Flood control only	$279,000	$398,000	1.43 to 1
Increasing low flow only	269,000	503,000	1.87 to 1
Dual-purpose, flood control and increasing low flow	376,000	901,000	2.40 to 1

ALLOCATION OF COSTS

General. - The operation of Monroe Reservoir will have far reaching effects that will take it out of the realm of a purely local project. The flood control benefits will extend to the Wabash, Ohio and Mississippi Rivers and will affect Illinois, Kentucky and other states as well as a large area in Indiana. The benefits from increasing low flow downstream from the dam will benefit Illinois and Indiana equally along the lower Wabash River and will be an aid to navigation on the Ohio and Mississippi Rivers.

Because of these circumstances the project has been considered as properly being eligible for inclusion in the Federal flood control program for the Ohio River basin as being developed by the Corps of Engineers. It is on this basis that all planning has been done. Close coordination with the Louisville District, Corps of Engineers, has been maintained at every step in the preparation of this report.

The existing Federal policy concerning the requirements for local cooperation (sharing of cost) is given in Section 3 of the 1944 Flood Control Act (Public Law 534, 78th Congress). The provisions of that Act, as supplemented by Federal policy decisions and interpretations, provides that the Federal Government will bear all reservoir costs allocated to flood control except in the instance where the reservoir project results in higher utilization of land in addition to flood prevention benefits. In the latter event it is considered equitable that non-Federal interests contribute a proportionate share of the project costs. That share is based on 50 percent of the ratio that the higher land utilization benefits bear to the total flood control benefits. Inclusion of increased low flow functions in a multiple purpose reservoir requires minimum contributions equal to the separable costs plus a proportional share of the joint costs.

Allocation of costs. - The proposed Monroe Reservoir has the dual purposes of protecting the areas downstream from floods and of increasing the low flow of streams by the release of water from storage during periods of low flow. The cost of the provision of each of these features in the reservoir was ascertained by allocating proportionate shares of the total estimated construction costs and the annual cost of operation and maintenance after construction to these purposes. To determine the allocation of costs for each function of the dual-purpose reservoir, separate cost estimates were prepared for single-purpose reservoirs for flood control and for increasing low flow, each designed to accomplish the same results as would be obtained by that feature in the dual-purpose reservoir. The costs of a flood control reservoir and an increased low flow reservoir, each operating as a single purpose reservoir, are estimated by the Corps of Engineers to be $6,980,000 and $6,820,000, respectively. The estimated cost of the multiple-purpose reservoir is $9,500,000.

Using these single-purpose reservoir cost estimates, the separable costs and remaining benefit method was used to obtain the cost to be allocated to each function of the reservoir. Utilization of this method of cost allocation insures that each purpose included in a multiple-purpose reservoir project receives an equitable share in the savings resulting from a combined purpose reservoir.

The separable costs in a dual-purpose project are determined by subtracting the cost of a single-purpose project, such as flood control, from the dual-purpose cost to obtain a remaining cost that may be attributed to the other purpose of increasing low flow. This process is then repeated using the cost of the single-purpose project for increasing low flow to obtain a remaining cost for flood control. As the sum of the two remaining costs will not equal the dual purpose cost, the difference is considered a joint cost and is divided between the two purposes. The separate remaining costs plus the divided joint costs then become the costs to be allocated to each purpose. The allocation of operation and maintenance costs is determined in a similar manner.

The allocation of reservoir first costs, annual charges, annual operation and maintenance, and annual benefits for the Monroe multiple-purpose project are summarized in Table XXIV.

TABLE XXIV

ALLOCATION OF COSTS AND BENEFITS BY PURPOSE

Item	Purpose		
	Flood Control	Increasing low flows	Multiple
First cost	$4,820,000	$4,680,000	$9,500,000
Annual charges (first cost)	173,000	168,000	341,000
Annual operation and maintenance	20,000	15,000	35,000
Annual benefits	398,000	503,000	901,000

The portion of the costs of flood control to be contributed by local interests is based on one-half of the proportionate part that higher land utilization benefits are to the total flood control benefits. The anticipated higher land utilization benefits that are expected to accrue to operation of Monroe Reservoir are estimated to be $6,000 annually. These benefits are 1.50 percent of the total flood control benefits and, therefore, would require a contribution by local interests of 0.75 percent of the allocated first cost of $4,810,000 for flood control. This cost will amount to $36,000 and is in addition to the previously allocated cost for increasing low flow, also to be borne by local interests.

The annual value of operation and maintenance costs chargeable to increasing low flow represents the average expenditures that can be anticipated over the life of the project and includes replacements of items of equipment as well as normal operation and maintenance expenses. In view of these variable expenditures, it is considered that a lump sum payment equal to the present value of the average operation and maintenance expenses is desirable from local interests. The present value of these annual expenses ($15,000) based on the life of the project and using a 2.5 percent interest rate, is $425,000. As local interests are required to contribute all costs for the provision of increased low flow features in the reservoir this sum is added to the allocated first cost for increasing low flow.

Summary of final cost allocation. - Based on the previously presented allocation and as modified by the preceding discussions, the final cost allocations between the Federal Government and local interests are presented in Table XXV. It should be noticed that the local interests share of flood control first costs and added to the non-Federal first costs. Also, that the non-Federal allocated costs include $425,000 which represents the present capital value of operation and maintenance expenses to be paid by local interests in lieu of the annual operation and maintenance charges of $15,000.

TABLE XXV

SUMMARY OF COST ALLOCATIONS

Item	Federal	Non-Federal	Total
First cost allocation	$4,820,000	$4,680,000	$9,500,000
Adjustment (higher land utilization)	-36,000	+36,000	—
Adjusted first cost allocation	4,784,000	4,716,000	9,500,000
Capital value of non-Federal operation and maintenance costs	—	425,000	425,000
Total allocation	$4,784,000	$5,141,000	$9,925,000

CONCLUSION AND RECOMMENDATION

Conclusion. - Monroe Reservoir is considered to be a desirable project for flood control and for increasing the low flow in Salt Creek, East Fork of White, White and Wabash Rivers downstream from the dam. The reservoir, as a part of a comprehensive plan for flood control in the Ohio River basin, also would provide benefits to the lower Ohio and Mississippi Rivers.

The largest returns in benefits from the operation of the reservoir would be found in Indiana, extending far downstream from the dam. The greater protection from floods and the enlarged supply of water for industry will be of tremendous value to the entire economy of southern Indiana.

The total average annual benefits accruing to Monroe Reservoir are estimated at $901,000, which includes $398,000 in flood control benefits and $503,000 in increased low flow benefits. The estimated first cost of $9,500,000 is allocated in the amount of $4,820,000 to flood control and $4,680,000 to increasing low flow.

The total capital amount currently apportioned to local interests is estimated at $5,141,000, including a $36,000 charge for higher land utilization benefits and a capitalized amount of $425,000 representing a proportional part of annual operation and maintenance allocated to increased low flow regulation. The local interests share is 54.1 percent of the first cost.

The total annual charges for the reservoir project are estimated at $376,000, resulting in an economic ratio of benefits to costs of 2.40 to one.

The Monroe Reservoir is planned as a part of the master or comprehensive plan for the entire state to control floods and to accumulate, preserve and protect the water resources. It is considered compatible with other possible improvements for solution of the remaining flood control and low flow problems in the White River basin and is the most suitable plan for early selection and development.

It is concluded that the primary benefits of flood control and low flow regulation would exceed the costs of the proposed project and that substantial subordinate and intangible benefits that cannot be evaluated also would be derived.

Recommendation. - It is recommended that the Monroe Reservoir project for flood control and for increasing the low flow of East Fork of White and White Rivers be authorized for construction by the State and Federal governments as outlined in this report, at a total estimated cost of $9,500,000 and $35,000 annually for maintenance and operation. It is further recommended, under present Federal policies on such projects and because of the widespread distribution of benefits that affect the overall economy of Indiana, that the State assume the local interests or non-Federal share of the cost. This share is 54.1 percent of the first cost. The cost to the State, based upon present day conditions and prices and including a capitalized amount representing a proportional part of operation and maintenance, would amount to $5,141,000 unless the Federal policy should be changed to include this cost.

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